

Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

column C1, Floor 1

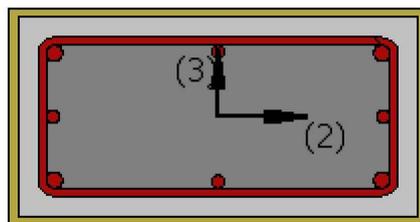
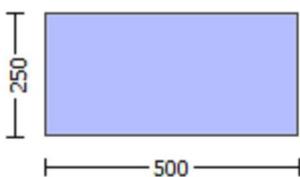
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

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, $M_a = -9.3362E+006$

Shear Force, $V_a = -3085.676$

EDGE -B-

Bending Moment, $M_b = 76808.128$

Shear Force, $V_b = 3085.676$

BOTH EDGES

Axial Force, $F = -4810.556$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression: $A_{sl,c} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 829.3805$

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

-Middle: $A_{sl,mid} = 402.1239$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 316023.074$

V_n ((10.3), ASCE 41-17) = $k_n l V_{CoI} = 316023.074$

$V_{CoI} = 316023.074$

$k_n l = 1.00$

displacement_ductility_demand = 0.02290923

NOTE: In expression (10-3) ' $V_s = A_v f_y d/s$ ' is replaced by ' $V_s + \phi V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

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

$M/Vd = 4.00$

$M_u = 9.3362E+006$

$V_u = 3085.676$

$d = 0.8 \cdot h = 400.00$
 $Nu = 4810.556$
 $Ag = 125000.00$
 From (11.5.4.8), ACI 318-14: $Vs = 147839.654$
 $Av = 157079.633$
 $fy = 400.00$
 $s = 170.00$
 Vs is multiplied by $Col = 1.00$
 $s/d = 0.425$
 Vf ((11-3)-(11.4), ACI 440) = 240803.347
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \csc)\sin\alpha$ which is more a generalised expression,
 where α is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(\alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\alpha = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, \alpha)|, |Vf(-45, \alpha)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / \text{NoDir} = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 457.00
 ffe ((11-5), ACI 440) = 259.312
 $Ef = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.01$
 From (11-11), ACI 440: $Vs + Vf \leq 265721.532$
 $bw = 250.00$

 displacement ductility demand is calculated as δ / y

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

 From analysis, chord rotation $\theta = 0.00016088$
 $y = (My \cdot Ls / 3) / Eleff = 0.00702237$ ((4.29), Biskinis Phd))
 $My = 1.1434E+008$
 $Ls = M/V$ (with $Ls > 0.1 \cdot L$ and $Ls < 2 \cdot L$) = 3025.674
 From table 10.5, ASCE 41_17: $Eleff = \text{factor} \cdot Ec \cdot Ig = 1.6421E+013$
 $\text{factor} = 0.30$
 $Ag = 125000.00$
 $fc' = 20.00$
 $N = 4810.556$
 $Ec \cdot Ig = 5.4737E+013$

 Calculation of Yielding Moment My

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

 $y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.5287315E-006$
 with ((10.1), ASCE 41-17) $fy = \text{Min}(fy, 1.25 \cdot fy \cdot (lb/d)^{2/3}) = 291.1836$
 $d = 457.00$
 $y = 0.29653227$
 $A = 0.01818298$
 $B = 0.01001242$
 with $pt = 0.00725935$
 $pc = 0.00725935$
 $pv = 0.00351968$
 $N = 4810.556$
 $b = 250.00$
 $\alpha = 0.0940919$
 $y_{comp} = 1.2979423E-005$
 with $fc' (12.3, (ACI 440)) = 20.44585$
 $fc = 20.00$

$f_l = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $A_g = 125000.00$
From (12.9), ACI 440: $k_a = 0.15087868$
 $g = p_t + p_c + p_v = 0.01803838$
 $rc = 40.00$
 $A_e/A_c = 0.60351471$
Effective FRP thickness, $t_f = NL * t * \cos(\theta_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.29518426$
 $A = 0.01791814$
 $B = 0.00986782$
with $E_s = 200000.00$

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.37945973$

$l_b = 300.00$

$l_d = 790.5977$

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

$= 1$

$d_b = 18.00$

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

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

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

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

$s = 170.00$

$n = 8.00$

End Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 2

column C1, Floor 1

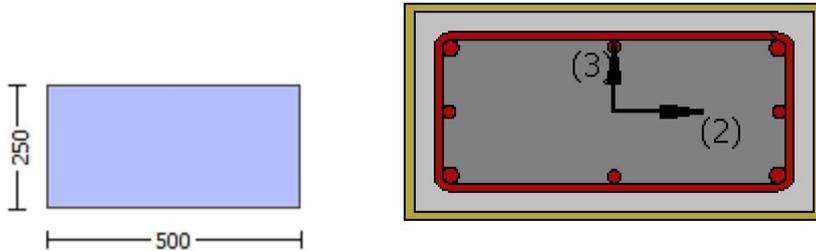
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_u)

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

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, Va = 2.9007121E-031
EDGE -B-
Shear Force, Vb = -2.9007121E-031
BOTH EDGES
Axial Force, F = -4666.932
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 2060.885
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 829.3805
-Compression: Asl,com = 829.3805
-Middle: Asl,mid = 402.1239

Calculation of Shear Capacity ratio , $V_e/V_r = 0.15063296$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 39953.171$
with
 $M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 5.9930E+007$
 $M_{u1+} = 5.9930E+007$, 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
 $M_{u1-} = 5.9930E+007$, 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
 $M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 5.9930E+007$
 $M_{u2+} = 5.9930E+007$, 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
 $M_{u2-} = 5.9930E+007$, 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:
 $\phi_u = 3.4011160E-005$
 $M_u = 5.9930E+007$

with full section properties:

$b = 500.00$
 $d = 207.00$
 $d' = 43.00$
 $v = 0.00225456$
 $N = 4666.932$
 $f_c = 20.00$
 α_1 (5A.5, TBDY) = 0.002
Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01464474$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_{cu} = 0.01464474$
 ϕ_{ve} ((5.4c), TBDY) = $\alpha_1 * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07762821$
where $\phi_f = \alpha_1 * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\phi_{fx} = 0.07705054$
 $\phi_{fy} = 0.45253333$
 $b = 500.00$
 $h = 250.00$
From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.004064$

bw = 500.00
effective stress from (A.35), $f_{f,e} = 837.9178$

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $f_{f,e} = 703.4155$

R = 40.00
Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.001848

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) = 0.001848
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

with $fs1 = fs = 313.6681$

with $Es1 = Es = 200000.00$

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered

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

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

with $f_{s2} = f_s = 313.6681$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.00130695$

$sh_v = 0.00451687$

$ft_v = 376.4017$

$f_{yv} = 313.6681$

$s_{uv} = 0.005257$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30356779$

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

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

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

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

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

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

with $f_{sv} = f_s = 313.6681$

with $E_{sv} = E_s = 200000.00$

1 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.1256764$

2 = $A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.1256764$

v = $A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.06093401$

and confined core properties:

b = 440.00

d = 177.00

d' = 13.00

f_{cc} (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.16701987$

2 = $A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.16701987$

v = $A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08097933$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

μ_u (4.9) = 0.25329952

$M_u = M_{Rc}$ (4.14) = 5.9930E+007

u = μ_u (4.1) = 3.4011160E-005

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

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

= 1

$d_b = 18.00$

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

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

K_{tr} = 4.61999

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

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

s = 170.00

n = 8.00

Calculation of μ_{u1} -

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

$$u = 3.4011160E-005$$

$$\mu = 5.9930E+007$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00225456$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.01464474$$

$$\phi_{we} \text{ ((5.4c), TBDY)} = \alpha_{se} * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$$

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

$$\phi_x = 0.07705054$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 837.9178$$

$$\phi_y = 0.12936483$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$bw = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TBDY)} = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$\text{psh}_{, \text{min}} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.001848$$

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

$$\text{psh}_x \text{ (5.4d)} = 0.001848$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$\text{psh}_y \text{ (5.4d)} = 0.00369599$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y1 = 0.00130695$$

$$\text{sh}_1 = 0.00451687$$

$$ft1 = 376.4017$$

$$fy1 = 313.6681$$

$$su1 = 0.005257$$

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

$$lo/lo_{u,min} = lb/l_d = 0.30356779$$

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

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

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

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

$$\text{with } fs1 = fs = 313.6681$$

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

$$y2 = 0.00130695$$

$$sh2 = 0.00451687$$

$$ft2 = 376.4017$$

$$fy2 = 313.6681$$

$$su2 = 0.005257$$

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

$$lo/lo_{u,min} = lb/l_{b,min} = 0.30356779$$

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

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

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

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

$$\text{with } fs2 = fs = 313.6681$$

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

$$yv = 0.00130695$$

$$shv = 0.00451687$$

$$ftv = 376.4017$$

$$fyv = 313.6681$$

$$suv = 0.005257$$

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

$$lo/lo_{u,min} = lb/l_d = 0.30356779$$

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

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

$$\text{with } fsv = fs = 313.6681$$

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

$$1 = Asl_{ten}/(b*d)*(fs1/fc) = 0.1256764$$

$$2 = Asl_{com}/(b*d)*(fs2/fc) = 0.1256764$$

$$v = Asl_{mid}/(b*d)*(fsv/fc) = 0.06093401$$

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = Asl_{ten}/(b*d)*(fs1/fc) = 0.16701987$$

$$2 = Asl_{com}/(b*d)*(fs2/fc) = 0.16701987$$

$$v = Asl_{mid}/(b*d)*(fsv/fc) = 0.08097933$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su (4.9) = 0.25329952$$

$$Mu = MRc (4.14) = 5.9930E+007$$

$$u = s_u(4.1) = 3.4011160E-005$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.30356779$

$$l_b = 300.00$$

$$d = 988.2471$$

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

$$= 1$$

$$d_b = 18.00$$

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

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

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

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of μ_{2+}

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

$$u = 3.4011160E-005$$

$$\mu = 5.9930E+007$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00225456$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464474$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01464474$$

$$w_e((5.4c), \text{ TBDY}) = a_s e^* s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

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

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

u,f = 0.015

ase ((5.4d), TBDY) = 0.03751166

bo = 440.00

ho = 190.00

bi2 = 459400.00

psh,min = Min(psh,x , psh,y) = 0.001848

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) = 0.001848

Ash = Astir*ns = 78.53982

No stirrups, ns = 2.00

bk = 500.00

psh,y (5.4d) = 0.00369599

Ash = Astir*ns = 78.53982

No stirrups, ns = 2.00

bk = 250.00

s = 170.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158

c = confinement factor = 1.13916

y1 = 0.00130695

sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695

sh2 = 0.00451687

ft2 = 376.4017

fy2 = 313.6681

su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695

shv = 0.00451687

ftv = 376.4017

fyv = 313.6681

suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

For calculation of $e_{suv_nominal}$ and y_v , sh_v, ft_v, 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, ASCE41-17.

with $f_{sv} = f_s = 313.6681$

with $E_{sv} = E_s = 200000.00$

1 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.1256764$

2 = $A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.1256764$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.06093401$

and confined core properties:

$b = 440.00$

$d = 177.00$

$d' = 13.00$

f_{cc} (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.16701987$

2 = $A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.16701987$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08097933$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

μ_u (4.9) = 0.25329952

$M_u = M_{Rc}$ (4.14) = 5.9930E+007

$u = \mu_u$ (4.1) = 3.4011160E-005

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

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

= 1

$d_b = 18.00$

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

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 4.61999$

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

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

$s = 170.00$

$n = 8.00$

Calculation of μ_u

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

$u = 3.4011160E-005$

$M_u = 5.9930E+007$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00225456$

$N = 4666.932$

$f_c = 20.00$

cc (5A.5, TBDY) = 0.002

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464474$

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

From (5.4b), TBDY: $c_u = 0.01464474$

w_e ((5.4c), TBDY) = $ase * sh_{\min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$

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

 $f_x = 0.07705054$

$af = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{f,e} = 837.9178$

 $f_y = 0.12936483$

$af = 0.45253333$

$b = 250.00$

$h = 500.00$

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

$bw = 250.00$

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

 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

ase ((5.4d), TBDY) = 0.03751166

$bo = 440.00$

$ho = 190.00$

$bi2 = 459400.00$

$psh_{\min} = \text{Min}(psh_x, psh_y) = 0.001848$

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) = 0.001848

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$bk = 500.00$

 psh_y (5.4d) = 0.00369599

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$bk = 250.00$

 $s = 170.00$

$fy_{we} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$

$c = \text{confinement factor} = 1.13916$

$y1 = 0.00130695$

$sh1 = 0.00451687$

$ft1 = 376.4017$

$fy1 = 313.6681$

$su1 = 0.005257$

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

$lo/lo_{\min} = lb/ld = 0.30356779$

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

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

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

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

with $fs1 = fs = 313.6681$

with $Es1 = Es = 200000.00$

$y2 = 0.00130695$

$$sh2 = 0.00451687$$

$$ft2 = 376.4017$$

$$fy2 = 313.6681$$

$$su2 = 0.005257$$

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

$$lo/lo_{u,min} = lb/lb_{u,min} = 0.30356779$$

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

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

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

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

$$\text{with } fs2 = fs = 313.6681$$

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

$$yv = 0.00130695$$

$$shv = 0.00451687$$

$$ftv = 376.4017$$

$$fyv = 313.6681$$

$$suv = 0.005257$$

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

$$lo/lo_{u,min} = lb/ld = 0.30356779$$

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

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

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

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

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

$$\text{with } fsv = fs = 313.6681$$

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

$$1 = Asl_{ten}/(b*d) * (fs1/fc) = 0.1256764$$

$$2 = Asl_{com}/(b*d) * (fs2/fc) = 0.1256764$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.06093401$$

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = Asl_{ten}/(b*d) * (fs1/fc) = 0.16701987$$

$$2 = Asl_{com}/(b*d) * (fs2/fc) = 0.16701987$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.08097933$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < vsy2$ - LHS eq.(4.5) is satisfied

$$su (4.9) = 0.25329952$$

$$Mu = MRc (4.14) = 5.9930E+007$$

$$u = su (4.1) = 3.4011160E-005$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$

$$lb = 300.00$$

$$ld = 988.2471$$

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

$$= 1$$

$$db = 18.00$$

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

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

$$t = 1.00$$

$$s = 0.80$$

$e = 1.00$
 $cb = 25.00$
 $Ktr = 4.61999$
 $Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis
 $s = 170.00$
 $n = 8.00$

 Calculation of Shear Strength $Vr = \text{Min}(Vr1, Vr2) = 265235.248$

 Calculation of Shear Strength at edge 1, $Vr1 = 265235.248$
 $Vr1 = VCol$ ((10.3), ASCE 41-17) = $knl * VCol0$
 $VCol0 = 265235.248$
 $knl = 1$ (zero step-static loading)

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

 $= 1$ (normal-weight concrete)
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$Mu = 2.3992784E-012$

$Vu = 2.9007121E-031$

$d = 0.8 * h = 200.00$

$Nu = 4666.932$

$Ag = 125000.00$

From (11.5.4.8), ACI 318-14: $Vs = 49279.392$

$Av = 157079.633$

$fy = 444.44$

$s = 170.00$

Vs is multiplied by $Col = 0.60$

$s/d = 0.85$

Vf ((11-3)-(11.4), ACI 440) = 109072.851

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

$dfv = d$ (figure 11.2, ACI 440) = 207.00

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

$Ef = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $Vs + Vf \leq 297085.704$

$bw = 500.00$

 Calculation of Shear Strength at edge 2, $Vr2 = 265235.248$

$Vr2 = VCol$ ((10.3), ASCE 41-17) = $knl * VCol0$

$VCol0 = 265235.248$

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

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

 $= 1$ (normal-weight concrete)

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

$M/Vd = 2.00$

$Mu = 2.3992784E-012$

$Vu = 2.9007121E-031$

$d = 0.8 \cdot h = 200.00$
 $Nu = 4666.932$
 $Ag = 125000.00$
 From (11.5.4.8), ACI 318-14: $Vs = 49279.392$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 170.00$
 Vs is multiplied by $Col = 0.60$
 $s/d = 0.85$
 Vf ((11-3)-(11.4), ACI 440) = 109072.851
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 207.00
 ffe ((11-5), ACI 440) = 259.312
 $Ef = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.01$
 From (11-11), ACI 440: $Vs + Vf \leq 297085.704$
 $bw = 500.00$

 End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At local axis: 3

 Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rcrs

Constant Properties

 Knowledge Factor, $\gamma = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Primary Member: Concrete Strength, $fc = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $fs = f_{sm} = 444.44$
 Concrete Elasticity, $Ec = 21019.039$
 Steel Elasticity, $Es = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $fs = 1.25 \cdot f_{sm} = 555.55$
 #####
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.13916
 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, $bi = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 1.3558547E-031$
EDGE -B-
Shear Force, $V_b = -1.3558547E-031$
BOTH EDGES
Axial Force, $F = -4666.932$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{l,ten} = 829.3805$
-Compression: $As_{l,com} = 829.3805$
-Middle: $As_{l,mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.23676754$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96937.922$
with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.4541E+008$
 $Mu_{1+} = 1.4541E+008$, 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
 $Mu_{1-} = 1.4541E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.4541E+008$
 $Mu_{2+} = 1.4541E+008$, 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
 $Mu_{2-} = 1.4541E+008$, 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:
 $\phi_u = 1.4467178E-005$
 $Mu = 1.4541E+008$

with full section properties:

$b = 250.00$
 $d = 457.00$
 $d' = 43.00$
 $v = 0.00204242$
 $N = 4666.932$
 $f_c = 20.00$
 ϕ_o (5A.5, TBDY) = 0.002
Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_o) = 0.01464474$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_u = 0.01464474$
 ω_e ((5.4c), TBDY) = $a_s e^* \phi_{u, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{ux}, \phi_{uy}) = 0.07762821$
where $\phi = a_f * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.07705054
af = 0.45253333
b = 500.00
h = 250.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.004064
bw = 500.00
effective stress from (A.35), ff,e = 837.9178

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128
bw = 250.00
effective stress from (A.35), ff,e = 703.4155

R = 40.00
Effective FRP thickness, tf = NL*t*cos(b1) = 1.016
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00

psh,min = Min(psh,x , psh,y) = 0.001848
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) = 0.001848
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

with fs1 = fs = 313.6681
with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695

shv = 0.00451687

ftv = 376.4017

fyv = 313.6681

suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

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

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127

2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127

v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062

and confined core properties:

b = 190.00

d = 427.00

d' = 13.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1603292

2 = Asl,com/(b*d)*(fs2/fc) = 0.1603292

v = Asl,mid/(b*d)*(fsv/fc) = 0.07773537

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.20486988

Mu = MRc (4.14) = 1.4541E+008

u = su (4.1) = 1.4467178E-005

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.30356779

lb = 300.00

ld = 988.2471

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

= 1

db = 18.00

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

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 4.61999

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 = 170.00
n = 8.00

Calculation of Mu1-

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

$u = 1.4467178E-005$

$Mu = 1.4541E+008$

with full section properties:

b = 250.00

d = 457.00

d' = 43.00

v = 0.00204242

N = 4666.932

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$

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

From (5.4b), TBDY: $\phi_u = 0.01464474$

ϕ_{we} ((5.4c), TBDY) = $\text{ase} * \text{sh_min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$

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

 $\phi_x = 0.07705054$

$\text{af} = 0.45253333$

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.004064$

$b_w = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

 $\phi_y = 0.12936483$

$\text{af} = 0.45253333$

b = 250.00

h = 500.00

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

$b_w = 250.00$

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

R = 40.00

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

ase ((5.4d), TBDY) = 0.03751166

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$\text{psh_min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.001848$

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) = 0.001848

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 500.00$

 psh_y (5.4d) = 0.00369599

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 250.00$

s = 170.00

$$fy_{we} = 555.55$$

$$f_{ce} = 20.00$$

From (5A.5), TBDY, TBDY: $cc = 0.00339158$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00130695$$

$$sh_1 = 0.00451687$$

$$ft_1 = 376.4017$$

$$fy_1 = 313.6681$$

$$su_1 = 0.005257$$

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

$$lo/lo_{u,min} = lb/ld = 0.30356779$$

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

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

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

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

$$\text{with } fs_1 = fs = 313.6681$$

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

$$y_2 = 0.00130695$$

$$sh_2 = 0.00451687$$

$$ft_2 = 376.4017$$

$$fy_2 = 313.6681$$

$$su_2 = 0.005257$$

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

$$lo/lo_{u,min} = lb/lb_{,min} = 0.30356779$$

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

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

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

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

$$\text{with } fs_2 = fs = 313.6681$$

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

$$y_v = 0.00130695$$

$$sh_v = 0.00451687$$

$$ft_v = 376.4017$$

$$fy_v = 313.6681$$

$$su_v = 0.005257$$

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

$$lo/lo_{u,min} = lb/ld = 0.30356779$$

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

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

considering characteristic value $fsy_v = fs_v/1.2$, from table 5.1, TBDY
For calculation of $esu_{v,nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsy_v = fs_v/1.2$, 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, ASCE41-17.

$$\text{with } fs_v = fs = 313.6681$$

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

$$1 = Asl_{,ten}/(b*d) * (fs_1/f_c) = 0.11385127$$

$$2 = Asl_{,com}/(b*d) * (fs_2/f_c) = 0.11385127$$

$$v = Asl_{,mid}/(b*d) * (fs_v/f_c) = 0.05520062$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = Asl_{,ten}/(b*d) * (fs_1/f_c) = 0.1603292$$

$$2 = Asl_{,com}/(b*d) * (fs_2/f_c) = 0.1603292$$

$$v = Asl_{,mid}/(b*d) * (fs_v/f_c) = 0.07773537$$

Case/Assumption: Unconfinedsd full section - Steel rupture

satisfies Eq. (4.3)

--->

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

--->

μ_u (4.9) = 0.20486988

μ_u = MRc (4.14) = 1.4541E+008

u = μ_u (4.1) = 1.4467178E-005

Calculation of ratio l_b/l_d

Lap Length: l_b/l_d = 0.30356779

l_b = 300.00

l_d = 988.2471

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

= 1

d_b = 18.00

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

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

t = 1.00

s = 0.80

e = 1.00

c_b = 25.00

K_{tr} = 4.61999

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 = 170.00

n = 8.00

Calculation of μ_{u2+}

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

u = 1.4467178E-005

μ_u = 1.4541E+008

with full section properties:

b = 250.00

d = 457.00

d' = 43.00

v = 0.00204242

N = 4666.932

f_c = 20.00

α (5A.5, TBDY) = 0.002

Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \alpha) = 0.01464474$

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

From (5.4b), TBDY: $\mu_u = 0.01464474$

where μ_u ((5.4c), TBDY) = $\alpha * \text{sh}_{\min} * f_y w_e / f_{c,e} + \text{Min}(f_x, f_y) = 0.07762821$

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

 f_x = 0.07705054

α = 0.45253333

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.004064$

b_w = 500.00

effective stress from (A.35), $f_{f,e} = 837.9178$

 f_y = 0.12936483

α = 0.45253333

b = 250.00

h = 500.00

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

b_w = 250.00

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

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} ((5.4d), TBDY) = 0.03751166$

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$

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)

$p_{sh,x} (5.4d) = 0.001848$

$A_{sh} = A_{stir} \cdot n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 500.00$

$p_{sh,y} (5.4d) = 0.00369599$

$A_{sh} = A_{stir} \cdot n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 250.00$

$s = 170.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.00339158$

$c = \text{confinement factor} = 1.13916$

$y_1 = 0.00130695$

$sh_1 = 0.00451687$

$ft_1 = 376.4017$

$fy_1 = 313.6681$

$su_1 = 0.005257$

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

$l_o/l_{o,min} = l_b/l_d = 0.30356779$

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

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, ASCE41-17.

with $f_{s1} = f_s = 313.6681$

with $E_{s1} = E_s = 200000.00$

$y_2 = 0.00130695$

$sh_2 = 0.00451687$

$ft_2 = 376.4017$

$fy_2 = 313.6681$

$su_2 = 0.005257$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30356779$

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

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

For calculation of esu2_nominal and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

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

with $f_{s2} = f_s = 313.6681$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.00130695$

$sh_v = 0.00451687$

$ft_v = 376.4017$

$fy_v = 313.6681$

$suv = 0.005257$

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

$$l_0/l_{0u,min} = l_b/l_d = 0.30356779$$

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

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

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

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

γ_1 , sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{sv} = f_s = 313.6681$$

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.11385127$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.11385127$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.05520062$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 22.78316$$

$$c_c (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.1603292$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.1603292$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

$$s_u (4.9) = 0.20486988$$

$$M_u = M_{Rc} (4.14) = 1.4541E+008$$

$$u = s_u (4.1) = 1.4467178E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$$l_b = 300.00$$

$$l_d = 988.2471$$

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

$$= 1$$

$$d_b = 18.00$$

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

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

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

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of M_u2 -

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

$$u = 1.4467178E-005$$

$$M_u = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

d = 457.00

d' = 43.00

v = 0.00204242

N = 4666.932

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01464474$

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

From (5.4b), TBDY: $cu = 0.01464474$

we ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.07762821$

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

fx = 0.07705054

af = 0.45253333

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

bw = 500.00

effective stress from (A.35), $ff_e = 837.9178$

fy = 0.12936483

af = 0.45253333

b = 250.00

h = 500.00

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

bw = 250.00

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

R = 40.00

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

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = 0.03751166

bo = 440.00

ho = 190.00

bi2 = 459400.00

psh,min = $\text{Min}(psh,x, psh,y) = 0.001848$

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) = 0.001848

Ash = $\text{Astir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 500.00

psh,y (5.4d) = 0.00369599

Ash = $\text{Astir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 250.00

s = 170.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$

c = confinement factor = 1.13916

y1 = 0.00130695

sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

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

lo/lou,min = $lb/d = 0.30356779$

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

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

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

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

with $fs1 = fs = 313.6681$

with $Es1 = Es = 200000.00$

$y2 = 0.00130695$

$sh2 = 0.00451687$

$ft2 = 376.4017$

$fy2 = 313.6681$

$su2 = 0.005257$

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

$lo/lou, min = lb/lb, min = 0.30356779$

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

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

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

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

with $fs2 = fs = 313.6681$

with $Es2 = Es = 200000.00$

$yv = 0.00130695$

$shv = 0.00451687$

$ftv = 376.4017$

$fyv = 313.6681$

$suv = 0.005257$

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

$lo/lou, min = lb/ld = 0.30356779$

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

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

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

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

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

with $fsv = fs = 313.6681$

with $Esv = Es = 200000.00$

1 = $Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.11385127$

2 = $Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.11385127$

v = $Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.05520062$

and confined core properties:

$b = 190.00$

$d = 427.00$

$d' = 13.00$

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = $Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.1603292$

2 = $Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.1603292$

v = $Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.07773537$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

su (4.9) = 0.20486988

$Mu = MRc$ (4.14) = 1.4541E+008

$u = su$ (4.1) = 1.4467178E-005

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$

$lb = 300.00$

$ld = 988.2471$

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

= 1

db = 18.00

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

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

$K_{tr} = 4.61999$

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

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

s = 170.00

n = 8.00

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 409422.352$

Calculation of Shear Strength at edge 1, $V_{r1} = 409422.352$

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

$V_{Col0} = 409422.352$

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

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

= 1 (normal-weight concrete)

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

$M/Vd = 2.00$

$\mu_u = 2.8180236E-013$

$\nu_u = 1.3558547E-031$

d = $0.8 * h = 400.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 164264.64$

$A_v = 157079.633$

$f_y = 444.44$

s = 170.00

V_s is multiplied by $\text{Col} = 1.00$

s/d = 0.425

V_f ((11-3)-(11.4), ACI 440) = 240803.347

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 $(\cot \theta + \text{cota}) \sin \alpha$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).

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

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 457.00

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: $V_s + V_f \leq 297085.704$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 409422.352$

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

$V_{Col0} = 409422.352$

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

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

= 1 (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 2.8180236E-013$
 $\nu_u = 1.3558547E-031$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 164264.64$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.425$
 V_f ((11-3)-(11.4), ACI 440) = 240803.347
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = 45^\circ + 90^\circ = 135^\circ$
 $V_f = \text{Min}(|V_f(45^\circ)|, |V_f(-45^\circ)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 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: $V_s + V_f \leq 297085.704$
 $b_w = 250.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
 At local axis: 2
 Integration Section: (a)
 Section Type: rcrs

Constant Properties

Knowledge Factor, $\phi = 1.00$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 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, $M = 6.5063436E-010$

Shear Force, $V_2 = -3085.676$

Shear Force, $V_3 = -2.2952864E-013$

Axial Force, $F = -4810.556$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression: $A_{sl,c} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 829.3805$

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

-Middle: $A_{sl,mid} = 402.1239$

Mean Diameter of Tension Reinforcement, $D_bL = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = u = 0.00620875$

$u = y + p = 0.00620875$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00620875$ ((4.29), Biskinis Phd)

$M_y = 5.0977E+007$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1053E+012$

factor = 0.30

$A_g = 125000.00$

$f_c' = 20.00$

$N = 4810.556$

$E_c * I_g = 1.3684E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$y_{ten} = 1.0451269E-005$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 291.1836$

$d = 207.00$

$y = 0.32702707$

$A = 0.02007155$

$B = 0.01218373$

with $pt = 0.00801334$

$pc = 0.00801334$

$p_v = 0.00388525$

$N = 4810.556$

$b = 500.00$

" = 0.20772947

$y_{comp} = 2.5958133E-005$

with $f_c * (12.3, (ACI 440)) = 20.44529$

$f_c = 20.00$

$f_l = 0.9425867$
 $b = 500.00$
 $h = 250.00$
 $A_g = 125000.00$
 From (12.9), ACI 440: $k_a = 0.1506892$
 $g = p_t + p_c + p_v = 0.01991193$
 $rc = 40.00$
 $A_e/A_c = 0.60275679$
 Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.32584352$
 $A = 0.0197792$
 $B = 0.01202411$
 with $E_s = 200000.00$

 Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.37945973$

$l_b = 300.00$
 $l_d = 790.5977$

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

$= 1$

$d_b = 18.00$

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

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

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

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

$s = 170.00$

$n = 8.00$

 - Calculation of p -

From table 10-8: $p = 0.00$

with:

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

shear control ratio $V_y E / V_{CoI} E = 0.15063296$

$d = 207.00$

$s = 0.00$

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

$A_v = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$b_w = 500.00$

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.

$NUD = 4810.556$

$A_g = 125000.00$

$f_c E = 20.00$

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

$p_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.01991193$

$b = 500.00$

$d = 207.00$

$f_c E = 20.00$

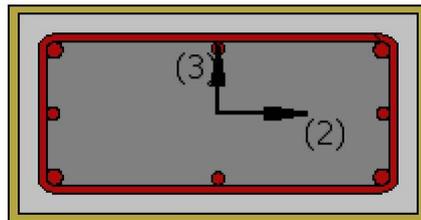
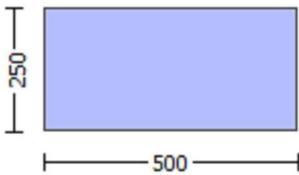
 End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

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 C1 of floor 1
- At local axis: 3
- Integration Section: (a)
- Section Type: rcrs

Constant Properties

- Knowledge Factor, $\gamma = 1.00$
- Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.
- Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
- Consequently:
- Existing material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$
- Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
- Concrete Elasticity, $E_c = 21019.039$
- Steel Elasticity, $E_s = 200000.00$
- #####
- Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).
- Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
- Existing material: Steel Strength, $f_s = f_{sm} = 444.44$
- #####
- Section Height, $H = 250.00$
- Section Width, $W = 500.00$
- 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, $M_a = 6.5063436E-010$
Shear Force, $V_a = -2.2952864E-013$
EDGE -B-
Bending Moment, $M_b = 3.8606651E-011$
Shear Force, $V_b = 2.2952864E-013$
BOTH EDGES
Axial Force, F = -4810.556
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 829.3805$
-Compression: $As_{c,com} = 829.3805$
-Middle: $As_{c,mid} = 402.1239$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 248574.19$
 V_n ((10.3), ASCE 41-17) = $k_n l V_{CoIO} = 248574.19$
 $V_{CoI} = 248574.19$
 $k_n l = 1.00$
displacement_ductility_demand = 0.00

NOTE: In expression (10-3) ' $V_s = A_v f_y d/s$ ' is replaced by ' $V_s + \phi V_f$ '
where V_f is the contribution of FRPs ((11.3), ACI 440).

= 1 (normal-weight concrete)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 6.5063436E-010$
 $V_u = 2.2952864E-013$
 $d = 0.8 \cdot h = 200.00$
 $N_u = 4810.556$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 44351.896$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 170.00$
 V_s is multiplied by $CoI = 0.60$
 $s/d = 0.85$
 V_f ((11-3)-(11.4), ACI 440) = 109072.851
 $\phi = 0.95$, for fully-wrapped sections

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

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \theta$ 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) = 207.00

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: $V_s + V_f \leq 265721.532$

$b_w = 500.00$

displacement ductility demand is calculated as δ / y

- Calculation of δ / y for END A -

for rotation axis 2 and integ. section (a)

From analysis, chord rotation $\theta = 4.3510689E-020$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00620875$ ((4.29), Biskinis Phd)

$M_y = 5.0977E+007$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 4.1053E+012$

factor = 0.30

$A_g = 125000.00$

$f_c' = 20.00$

$N = 4810.556$

$E_c \cdot I_g = 1.3684E+013$

Calculation of Yielding Moment M_y

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

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

$y_{ten} = 1.0451269E-005$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 291.1836$

$d = 207.00$

$y = 0.32702707$

$A = 0.02007155$

$B = 0.01218373$

with $p_t = 0.00801334$

$p_c = 0.00801334$

$p_v = 0.00388525$

$N = 4810.556$

$b = 500.00$

$\alpha = 0.20772947$

$y_{comp} = 2.5958133E-005$

with f_c' (12.3, (ACI 440)) = 20.44529

$f_c = 20.00$

$f_l = 0.9425867$

$b = 500.00$

$h = 250.00$

$A_g = 125000.00$

From (12.9), ACI 440: $k_a = 0.1506892$

$g = p_t + p_c + p_v = 0.01991193$

$r_c = 40.00$

$A_e / A_c = 0.60275679$

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 = 21019.039
y = 0.32584352
A = 0.0197792
B = 0.01202411
with Es = 200000.00

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.37945973$

$l_b = 300.00$

$l_d = 790.5977$

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

= 1

$d_b = 18.00$

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

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 4.61999$

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

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

$s = 170.00$

$n = 8.00$

End Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 4

column C1, Floor 1

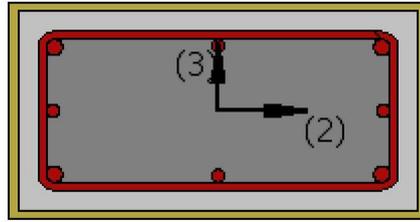
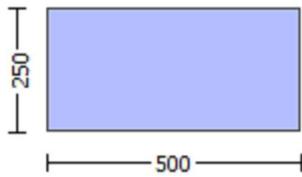
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

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

Constant Properties

Knowledge Factor, = 1.00

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

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, $V_a = 2.9007121E-031$

EDGE -B-

Shear Force, $V_b = -2.9007121E-031$

BOTH EDGES

Axial Force, $F = -4666.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 829.3805$

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

-Middle: $As_{c,mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.15063296$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 39953.171$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 5.9930E+007$

$Mu_{1+} = 5.9930E+007$, 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

$Mu_{1-} = 5.9930E+007$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 5.9930E+007$

$Mu_{2+} = 5.9930E+007$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 5.9930E+007$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of Mu_{1+}

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

$\phi_u = 3.4011160E-005$

$M_u = 5.9930E+007$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00225456$

$N = 4666.932$

$f_c = 20.00$

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

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_{co}) = 0.01464474$

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

From (5.4b), TBDY: $\phi_u = 0.01464474$

$\phi_{we} ((5.4c), TBDY) = a_s e * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$

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

$\phi_x = 0.07705054$

$a_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\phi_{pf} = 2t_f/b_w = 0.004064$

$b_w = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$\phi_y = 0.12936483$

$a_f = 0.45253333$

$b = 250.00$

$h = 500.00$

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

$b_w = 250.00$

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

$R = 40.00$

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

$f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase \text{ ((5.4d), TBDY)} = 0.03751166$
 $bo = 440.00$
 $ho = 190.00$
 $bi2 = 459400.00$

$psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.001848$
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)

 $psh_{,x} \text{ (5.4d)} = 0.001848$
 $A_{sh} = A_{stir} * n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $bk = 500.00$

 $psh_{,y} \text{ (5.4d)} = 0.00369599$
 $A_{sh} = A_{stir} * n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $bk = 250.00$

 $s = 170.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$

$y_1 = 0.00130695$
 $sh_1 = 0.00451687$
 $ft_1 = 376.4017$
 $fy_1 = 313.6681$
 $su_1 = 0.005257$

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

$lo/lo_{,min} = lb/ld = 0.30356779$

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

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

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

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

with $fs_1 = fs = 313.6681$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00130695$
 $sh_2 = 0.00451687$
 $ft_2 = 376.4017$
 $fy_2 = 313.6681$
 $su_2 = 0.005257$

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

$lo/lo_{,min} = lb/lb_{,min} = 0.30356779$

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

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

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

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

with $fs_2 = fs = 313.6681$

with $Es_2 = Es = 200000.00$

$y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $suv = 0.005257$

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

$lo/lo_{,min} = lb/ld = 0.30356779$

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

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

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

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

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

with $fsv = fs = 313.6681$

with $Esv = Es = 200000.00$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401$$

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$c =$ confinement factor $= 1.13916$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

$$su (4.9) = 0.25329952$$

$$Mu = MRc (4.14) = 5.9930E+007$$

$$u = su (4.1) = 3.4011160E-005$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$

$$lb = 300.00$$

$$ld = 988.2471$$

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

$$= 1$$

$$db = 18.00$$

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

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$Ktr = 4.61999$$

$$Atr = Min(Atr_x, Atr_y) = 157.0796$$

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of $Mu1$ -

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

$$u = 3.4011160E-005$$

$$Mu = 5.9930E+007$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00225456$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464474$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01464474$$

$$\text{we ((5.4c), TBDY)} = a_{se} * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

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

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh, \text{min}} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.001848$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00369599$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A.5), TBDY), TBDY: } c_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00130695$$

$$sh_1 = 0.00451687$$

$$ft_1 = 376.4017$$

$$fy_1 = 313.6681$$

$$su_1 = 0.005257$$

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

$$l_o / l_{o, \text{min}} = l_b / l_d = 0.30356779$$

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

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

For calculation of esu_1_{nominal} and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1 / 1.2$, from table 5.1, TBDY.

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

$$\text{with } fs_1 = fs = 313.6681$$

with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.00130695$
 $sh_2 = 0.00451687$
 $ft_2 = 376.4017$
 $fy_2 = 313.6681$
 $su_2 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_0/l_{ou,min} = l_b/l_{b,min} = 0.30356779$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 313.6681$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_0/l_{ou,min} = l_b/l_d = 0.30356779$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 313.6681$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b * d) * (fs_1/f_c) = 0.1256764$
 $2 = A_{sl,com}/(b * d) * (fs_2/f_c) = 0.1256764$
 $v = A_{sl,mid}/(b * d) * (fsv/f_c) = 0.06093401$
 and confined core properties:
 $b = 440.00$
 $d = 177.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b * d) * (fs_1/f_c) = 0.16701987$
 $2 = A_{sl,com}/(b * d) * (fs_2/f_c) = 0.16701987$
 $v = A_{sl,mid}/(b * d) * (fsv/f_c) = 0.08097933$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_s, y_2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.25329952$
 $M_u = MR_c (4.14) = 5.9930E+007$
 $u = su (4.1) = 3.4011160E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$
 $l_b = 300.00$
 $l_d = 988.2471$
 Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 20.00$, but $fc^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 4.61999
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 = 170.00
n = 8.00

Calculation of Mu2+

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

u = 3.4011160E-005
Mu = 5.9930E+007

with full section properties:

b = 500.00
d = 207.00
d' = 43.00
v = 0.00225456
N = 4666.932
fc = 20.00
co (5A.5, TBDY) = 0.002
Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_u = 0.01464474$
 ϕ_{we} ((5.4c), TBDY) = $\text{ase} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$
where $\phi = \text{af} * \text{pf} * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\phi_x = 0.07705054$
 $\text{af} = 0.45253333$
b = 500.00
h = 250.00
From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.004064$
b_w = 500.00
effective stress from (A.35), $f_{fe} = 837.9178$

 $\phi_y = 0.12936483$
 $\text{af} = 0.45253333$
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.008128$
b_w = 250.00
effective stress from (A.35), $f_{fe} = 703.4155$

R = 40.00
Effective FRP thickness, $t_f = \text{NL} * t * \text{Cos}(b_1) = 1.016$
 $f_{u,f} = 1055.00$
E_f = 64828.00
 $u_{f} = 0.015$
 ase ((5.4d), TBDY) = 0.03751166
b_o = 440.00
h_o = 190.00
b_i2 = 459400.00
 $\text{psh}_{\min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.001848$
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) = 0.001848
A_sh = A_stir * n_s = 78.53982
No stirrups, n_s = 2.00
b_k = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

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

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764

2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764

v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401

and confined core properties:

b = 440.00
d = 177.00
d' = 13.00

f_{cc} (5A.2, TBDY) = 22.78316
 c_c (5A.5, TBDY) = 0.00339158
 c = confinement factor = 1.13916
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16701987$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.16701987$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08097933$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

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

μ_u (4.9) = 0.25329952
 $M_u = M_{Rc}$ (4.14) = 5.9930E+007
 $u = \mu_u$ (4.1) = 3.4011160E-005

 Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$
 $l_b = 300.00$
 $l_d = 988.2471$

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

$d_b = 18.00$
 Mean strength value of all re-bars: $f_y = 555.55$
 $f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $c_b = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$
 where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

 Calculation of μ_u

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:
 $u = 3.4011160E-005$
 $M_u = 5.9930E+007$

 with full section properties:

$b = 500.00$
 $d = 207.00$
 $d' = 43.00$
 $v = 0.00225456$
 $N = 4666.932$
 $f_c = 20.00$
 c_c (5A.5, TBDY) = 0.002
 Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464474$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $c_u = 0.01464474$
 w_e ((5.4c), TBDY) = $a_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$
 where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07705054$
 $a_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$
 From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.004064$
 $b_w = 500.00$
 effective stress from (A.35), $f_{f,e} = 837.9178$

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128
bw = 250.00
effective stress from (A.35), ff,e = 703.4155

R = 40.00
Effective FRP thickness, tf = NL*t*Cos(b1) = 1.016
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00

psh,min = Min(psh,x , psh,y) = 0.001848
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) = 0.001848
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

with $f_s2 = f_s = 313.6681$
 with $E_s2 = E_s = 200000.00$
 $y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.30356779$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 313.6681$
 with $Esv = Es = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (fs1/fc) = 0.1256764$
 $2 = A_{sl,com}/(b*d) * (fs2/fc) = 0.1256764$
 $v = A_{sl,mid}/(b*d) * (fsv/fc) = 0.06093401$

and confined core properties:

$b = 440.00$
 $d = 177.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b*d) * (fs1/fc) = 0.16701987$
 $2 = A_{sl,com}/(b*d) * (fs2/fc) = 0.16701987$
 $v = A_{sl,mid}/(b*d) * (fsv/fc) = 0.08097933$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

$su (4.9) = 0.25329952$

$Mu = MRc (4.14) = 5.9930E+007$

$u = su (4.1) = 3.4011160E-005$

 Calculation of ratio lb/ld

 Lap Length: $lb/ld = 0.30356779$

$lb = 300.00$

$ld = 988.2471$

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

= 1

$db = 18.00$

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

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 4.61999$

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

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

$s = 170.00$

$n = 8.00$

 Calculation of Shear Strength $V_r = Min(V_{r1}, V_{r2}) = 265235.248$

Calculation of Shear Strength at edge 1, $Vr1 = 265235.248$

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

$VColO = 265235.248$

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

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

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

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

$M/Vd = 2.00$

$\mu = 2.3992784E-012$

$Vu = 2.9007121E-031$

$d = 0.8 * h = 200.00$

$Nu = 4666.932$

$Ag = 125000.00$

From (11.5.4.8), ACI 318-14: $Vs = 49279.392$

$Av = 157079.633$

$fy = 444.44$

$s = 170.00$

Vs is multiplied by $Col = 0.60$

$s/d = 0.85$

Vf ((11-3)-(11.4), ACI 440) = 109072.851

$f = 0.95$, for fully-wrapped sections

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

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

This later relation, considered as a function $Vf(\theta, \alpha)$, 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: $\theta = 45^\circ + 90^\circ = 135^\circ$

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

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

$dfv = d$ (figure 11.2, ACI 440) = 207.00

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

$Ef = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $Vs + Vf \leq 297085.704$

$bw = 500.00$

Calculation of Shear Strength at edge 2, $Vr2 = 265235.248$

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

$VColO = 265235.248$

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

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

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

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

$M/Vd = 2.00$

$\mu = 2.3992784E-012$

$Vu = 2.9007121E-031$

$d = 0.8 * h = 200.00$

$Nu = 4666.932$

$Ag = 125000.00$

From (11.5.4.8), ACI 318-14: $Vs = 49279.392$

$Av = 157079.633$

$fy = 444.44$

$s = 170.00$

Vs is multiplied by $Col = 0.60$

$s/d = 0.85$

Vf ((11-3)-(11.4), ACI 440) = 109072.851

$f = 0.95$, 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 $V_f(\theta)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

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

$V_f = \text{Min}(|V_f(45, b_1)|, |V_f(-45, a_1)|)$, with:

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 207.00

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: $V_s + V_f \leq 297085.704$

$b_w = 500.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

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, $\text{NoDir} = 1$

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, $V_a = 1.3558547E-031$

EDGE -B-

Shear Force, $V_b = -1.3558547E-031$

BOTH EDGES

Axial Force, $F = -4666.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{st,ten} = 829.3805$

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

-Middle: $A_{st,mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.23676754$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96937.922$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.4541E+008$

$M_{u1+} = 1.4541E+008$, 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

$M_{u1-} = 1.4541E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.4541E+008$

$M_{u2+} = 1.4541E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 1.4541E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of M_{u1+}

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

$\phi_u = 1.4467178E-005$

$M_u = 1.4541E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00204242$

$N = 4666.932$

$f_c = 20.00$

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

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$

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

From (5.4b), TBDY: $\phi_u = 0.01464474$

$\phi_{we} ((5.4c), TBDY) = \alpha_{se} * \phi_{sh,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$

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

$\phi_x = 0.07705054$

$\alpha_{se} = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\phi_{sh} = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$

$\alpha_{se} = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$
 $bw = 250.00$
effective stress from (A.35), $ff,e = 703.4155$

R = 40.00
Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase \text{ ((5.4d), TBDY)} = 0.03751166$
 $bo = 440.00$
 $ho = 190.00$
 $bi2 = 459400.00$
 $psh_{,min} = \text{Min}(psh,x, psh,y) = 0.001848$

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)

$psh,x \text{ (5.4d)} = 0.001848$
 $A_{sh} = A_{stir}*ns = 78.53982$
No stirrups, $ns = 2.00$
 $bk = 500.00$

$psh,y \text{ (5.4d)} = 0.00369599$
 $A_{sh} = A_{stir}*ns = 78.53982$
No stirrups, $ns = 2.00$
 $bk = 250.00$

$s = 170.00$
 $fy_{we} = 555.55$
 $f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$

$y1 = 0.00130695$
 $sh1 = 0.00451687$
 $ft1 = 376.4017$
 $fy1 = 313.6681$
 $su1 = 0.005257$

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

$lo/lou_{,min} = lb/ld = 0.30356779$

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

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

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

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

with $fs1 = fs = 313.6681$
with $Es1 = Es = 200000.00$

$y2 = 0.00130695$
 $sh2 = 0.00451687$
 $ft2 = 376.4017$
 $fy2 = 313.6681$
 $su2 = 0.005257$

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

$lo/lou_{,min} = lb/lb_{,min} = 0.30356779$

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

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

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

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

with $fs2 = fs = 313.6681$
with $Es2 = Es = 200000.00$

$yv = 0.00130695$
 $shv = 0.00451687$
 $ftv = 376.4017$

$$f_{yv} = 313.6681$$

$$s_{uv} = 0.005257$$

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

$$l_o/l_{ou,min} = l_b/l_d = 0.30356779$$

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

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, ASCE41-17.

$$\text{with } f_{sv} = f_s = 313.6681$$

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.11385127$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11385127$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.05520062$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 22.78316$$

$$c_c (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1603292$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1603292$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.20486988$$

$$M_u = M_{Rc} (4.14) = 1.4541E+008$$

$$u = s_u (4.1) = 1.4467178E-005$$

Calculation of ratio l_b/l_d

$$\text{Lap Length: } l_b/l_d = 0.30356779$$

$$l_b = 300.00$$

$$l_d = 988.2471$$

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

$$= 1$$

$$d_b = 18.00$$

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

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

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

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of M_{u1} -

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

$$u = 1.4467178E-005$$

$$M_u = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \alpha: \alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01464474$$

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

$$\text{From (5.4b), TBDY: } \alpha = 0.01464474$$

$$\omega_e ((5.4c), TBDY) = \alpha^* \cdot \text{sh}_{\min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

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

$$f_x = 0.07705054$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$f_y = 0.12936483$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$bw = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} ((5.4d), TBDY) = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$\rho_{sh,\min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.001848$$

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

$$\rho_{sh,x} (5.4d) = 0.001848$$

$$A_{sh} = A_{stir} \cdot n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$\rho_{sh,y} (5.4d) = 0.00369599$$

$$A_{sh} = A_{stir} \cdot n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \alpha_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00130695$$

$$\text{sh}_1 = 0.00451687$$

$$f_{t1} = 376.4017$$

$$f_{y1} = 313.6681$$

$$s_{u1} = 0.005257$$

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

$$l_o/l_{ou,\min} = l_b/d = 0.30356779$$

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

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

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

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

$$\text{with } fs_1 = fs = 313.6681$$

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

$$y_2 = 0.00130695$$

$$sh_2 = 0.00451687$$

$$ft_2 = 376.4017$$

$$fy_2 = 313.6681$$

$$su_2 = 0.005257$$

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

$$lo/lou, \text{min} = lb/lb, \text{min} = 0.30356779$$

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

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

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

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

$$\text{with } fs_2 = fs = 313.6681$$

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

$$y_v = 0.00130695$$

$$sh_v = 0.00451687$$

$$ft_v = 376.4017$$

$$fy_v = 313.6681$$

$$suv = 0.005257$$

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

$$lo/lou, \text{min} = lb/ld = 0.30356779$$

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

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

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

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

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

$$\text{with } fsv = fs = 313.6681$$

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

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.11385127$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.11385127$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.05520062$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.1603292$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.1603292$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

$$su (4.9) = 0.20486988$$

$$Mu = MRc (4.14) = 1.4541E+008$$

$$u = su (4.1) = 1.4467178E-005$$

Calculation of ratio lb/ld

$$\text{Lap Length: } lb/ld = 0.30356779$$

$$lb = 300.00$$

ld = 988.2471

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

= 1

db = 18.00

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

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 4.61999

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 = 170.00

n = 8.00

Calculation of Mu2+

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

u = 1.4467178E-005

Mu = 1.4541E+008

with full section properties:

b = 250.00

d = 457.00

d' = 43.00

v = 0.00204242

N = 4666.932

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$

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

From (5.4b), TBDY: $\phi_u = 0.01464474$

we ((5.4c), TBDY) = $\text{ase} * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$

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

$\phi_x = 0.07705054$

af = 0.45253333

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), pf = $2t_f / b_w = 0.004064$

b_w = 500.00

effective stress from (A.35), $f_{fe} = 837.9178$

$\phi_y = 0.12936483$

af = 0.45253333

b = 250.00

h = 500.00

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

b_w = 250.00

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

R = 40.00

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

f_u,f = 1055.00

E_f = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = 0.03751166

bo = 440.00

ho = 190.00

bi2 = 459400.00

psh,min = Min(psh_x, psh_y) = 0.001848

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) = 0.001848
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

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

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11385127$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.05520062$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 22.78316$$

$$c_c (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1603292$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1603292$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.20486988$$

$$M_u = M_{Rc} (4.14) = 1.4541E+008$$

$$u = s_u (4.1) = 1.4467178E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$$l_b = 300.00$$

$$l_d = 988.2471$$

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

$$= 1$$

$$d_b = 18.00$$

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

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

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

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of M_u2 -

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

$$u = 1.4467178E-005$$

$$M_u = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464474$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01464474$$

$$\text{we ((5.4c), TBDY) } = a_s * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

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

$$f_x = 0.07705054$$

af = 0.45253333
b = 500.00
h = 250.00
From EC8 A.4.4.3(6), pf = $2t_f/bw = 0.004064$
bw = 500.00
effective stress from (A.35), ff,e = 837.9178

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), pf = $2t_f/bw = 0.008128$
bw = 250.00
effective stress from (A.35), ff,e = 703.4155

R = 40.00
Effective FRP thickness, tf = $NL*t*Cos(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = $Min(psh,x, psh,y) = 0.001848$
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) = 0.001848
Ash = $Astir*ns = 78.53982$
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = $Astir*ns = 78.53982$
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = $lb/d = 0.30356779$
su1 = $0.4*esu1_nominal ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = $fs1/1.2$, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by $Min(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
with fs1 = fs = 313.6681
with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_{b,min} = 0.30356779$$

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

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

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

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

$$\text{with } f_{s2} = f_s = 313.6681$$

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

$$y_v = 0.00130695$$

$$sh_v = 0.00451687$$

$$ft_v = 376.4017$$

$$fy_v = 313.6681$$

$$s_{uv} = 0.005257$$

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

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

$$l_o/l_{o,u,min} = l_b/l_d = 0.30356779$$

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

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

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

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

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

$$\text{with } f_{sv} = f_s = 313.6681$$

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.11385127$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.11385127$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.05520062$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.1603292$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.1603292$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.20486988$$

$$\mu_u = M_{Rc} (4.14) = 1.4541E+008$$

$$u = s_u (4.1) = 1.4467178E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$$l_b = 300.00$$

$$l_d = 988.2471$$

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

$$= 1$$

$$d_b = 18.00$$

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

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

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

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 409422.352$

Calculation of Shear Strength at edge 1, $V_{r1} = 409422.352$

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

$V_{Col0} = 409422.352$

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

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

 $= 1$ (normal-weight concrete)

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

$M / Vd = 2.00$

$\mu_u = 2.8180236E-013$

$V_u = 1.3558547E-031$

$d = 0.8 * h = 400.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 164264.64$

$A_v = 157079.633$

$f_y = 444.44$

$s = 170.00$

V_s is multiplied by $Col = 1.00$

$s/d = 0.425$

V_f ((11-3)-(11.4), ACI 440) = 240803.347

$f = 0.95$, 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: $\alpha = b_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 457.00

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: $V_s + V_f \leq 297085.704$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 409422.352$

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

$V_{Col0} = 409422.352$

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

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

 $= 1$ (normal-weight concrete)

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

$M / Vd = 2.00$

$\mu_u = 2.8180236E-013$

$V_u = 1.3558547E-031$

$d = 0.8 * h = 400.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 164264.64$

$A_v = 157079.633$

$f_y = 444.44$

$s = 170.00$

Vs is multiplied by Col = 1.00

s/d = 0.425

Vf ((11-3)-(11.4), ACI 440) = 240803.347

f = 0.95, for fully-wrapped sections

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

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

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

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

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

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

dfv = d (figure 11.2, ACI 440) = 457.00

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 <= 297085.704

bw = 250.00

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
At local axis: 3
Integration Section: (a)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Section Height, H = 250.00

Section Width, W = 500.00

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, NoDir = 1

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

Number of layers, NL = 1

Radius of rounding corners, R = 40.00

Stepwise Properties

Bending Moment, $M = -9.3362E+006$
 Shear Force, $V2 = -3085.676$
 Shear Force, $V3 = -2.2952864E-013$
 Axial Force, $F = -4810.556$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 0.00$
 -Compression: $As_c = 2060.885$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{,ten} = 829.3805$
 -Compression: $As_{,com} = 829.3805$
 -Middle: $As_{,mid} = 402.1239$
 Mean Diameter of Tension Reinforcement, $Db_L = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = u = 0.00702237$
 $u = y + p = 0.00702237$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00702237$ ((4.29), Biskinis Phd)
 $M_y = 1.1434E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3025.674
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.6421E+013$
 factor = 0.30
 $A_g = 125000.00$
 $f_c' = 20.00$
 $N = 4810.556$
 $E_c * I_g = 5.4737E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{,ten}, y_{,com})$
 $y_{,ten} = 4.5287315E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 291.1836$
 $d = 457.00$
 $y = 0.29653227$
 $A = 0.01818298$
 $B = 0.01001242$
 with $pt = 0.00725935$
 $pc = 0.00725935$
 $p_v = 0.00351968$
 $N = 4810.556$
 $b = 250.00$
 $" = 0.0940919$
 $y_{,comp} = 1.2979423E-005$
 with $f_c^* (12.3, (ACI 440)) = 20.44585$
 $f_c = 20.00$
 $f_l = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $A_g = 125000.00$
 From (12.9), ACI 440: $ka = 0.15087868$
 $g = pt + pc + p_v = 0.01803838$
 $rc = 40.00$
 $A_e / A_c = 0.60351471$
 Effective FRP thickness, $t_f = NL * t * \text{Cos}(b1) = 1.016$
 effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$

y = 0.29518426
A = 0.01791814
B = 0.00986782
with Es = 200000.00

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.37945973$

$l_b = 300.00$

$l_d = 790.5977$

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

= 1

$d_b = 18.00$

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

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

t = 1.00

s = 0.80

e = 1.00

$c_b = 25.00$

$K_{tr} = 4.61999$

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

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

s = 170.00

n = 8.00

- Calculation of ρ -

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

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
shear control ratio $V_y E / V_{col} O E = 0.23676754$

$d = 457.00$

$s = 0.00$

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

$A_v = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$b_w = 250.00$

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.

$NUD = 4810.556$

$A_g = 125000.00$

$f_c E = 20.00$

$f_{tE} = f_{yE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.01803838$

$b = 250.00$

$d = 457.00$

$f_c E = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 5

column C1, Floor 1

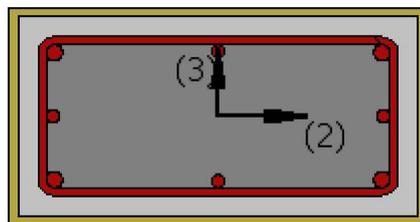
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

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, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -9.3362E+006$

Shear Force, $V_a = -3085.676$

EDGE -B-

Bending Moment, $M_b = 76808.128$

Shear Force, $V_b = 3085.676$

BOTH EDGES

Axial Force, $F = -4810.556$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression: $A_{sl,c} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 829.3805$

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

-Middle: $A_{sl,mid} = 402.1239$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = V_n = 366324.617$

V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{Co10} = 366324.617$

$V_{Co10} = 366324.617$

$k_n = 1.00$

$displacement_ductility_demand = 0.12428951$

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

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

$M / Vd = 2.00$

$M_u = 76808.128$

$V_u = 3085.676$

$d = 0.8 \cdot h = 400.00$

$N_u = 4810.556$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 147839.654$

$A_v = 157079.633$

$f_y = 400.00$

$s = 170.00$

V_s is multiplied by $Co1 = 1.00$

$s/d = 0.425$

V_f ((11-3)-(11.4), ACI 440) = 240803.347

$f = 0.95$, 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 $\alpha = 90^\circ$

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

total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 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: $V_s + V_f \leq 265721.532$
 $b_w = 250.00$

displacement ductility demand is calculated as δ / y

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

From analysis, chord rotation $\theta = 8.6540079E-005$
 $y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00069628$ ((4.29), Biskinis Phd)
 $M_y = 1.1434E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00
From table 10.5, ASCE 41_17: $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 1.6421E+013$
factor = 0.30
 $A_g = 125000.00$
 $f_c' = 20.00$
 $N = 4810.556$
 $E_c \cdot I_g = 5.4737E+013$

Calculation of Yielding Moment M_y

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

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 4.5287315E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (b/d)^{2/3}) = 291.1836$
 $d = 457.00$
 $y = 0.29653227$
 $A = 0.01818298$
 $B = 0.01001242$
with $p_t = 0.00725935$
 $p_c = 0.00725935$
 $p_v = 0.00351968$
 $N = 4810.556$
 $b = 250.00$
 $r = 0.0940919$
 $y_{\text{comp}} = 1.2979423E-005$
with $f_c' = 20.00$ (12.3, (ACI 440)) = 20.44585
 $f_l = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $A_g = 125000.00$
From (12.9), ACI 440: $k_a = 0.15087868$
 $g = p_t + p_c + p_v = 0.01803838$
 $r_c = 40.00$
 $A_e / A_c = 0.60351471$
Effective FRP thickness, $t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.29518426$
 $A = 0.01791814$
 $B = 0.00986782$
with $E_s = 200000.00$

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.37945973$

$l_b = 300.00$

$l_d = 790.5977$

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

$= 1$

$d_b = 18.00$

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

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

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

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

$s = 170.00$

$n = 8.00$

End Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 6

column C1, Floor 1

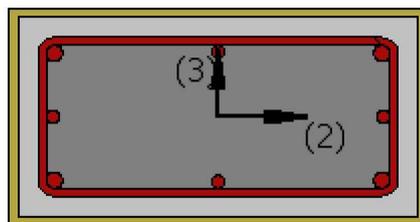
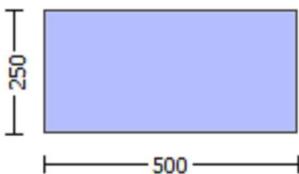
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ)

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)
Section Type: rcrs

Constant Properties

Knowledge Factor, $k = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

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, $V_a = 2.9007121E-031$

EDGE -B-

Shear Force, $V_b = -2.9007121E-031$

BOTH EDGES

Axial Force, $F = -4666.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression: $A_{sl,c} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 829.3805$

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

-Middle: $A_{sl,mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.15063296$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 39953.171$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 5.9930E+007$

$M_{u1+} = 5.9930E+007$, 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

$Mu_{1-} = 5.9930E+007$, 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

$Mpr_2 = \text{Max}(Mu_{2+}, Mu_{2-}) = 5.9930E+007$

$Mu_{2+} = 5.9930E+007$, 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

$Mu_{2-} = 5.9930E+007$, 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:

$\phi_u = 3.4011160E-005$

$Mu = 5.9930E+007$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00225456$

$N = 4666.932$

$f_c = 20.00$

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

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$

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

From (5.4b), TBDY: $\phi_u = 0.01464474$

$\phi_{we} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$

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

 $\phi_x = 0.07705054$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\phi_f = 2t_f / b_w = 0.004064$

$b_w = 500.00$

effective stress from (A.35), $f_{f,e} = 837.9178$

$\phi_y = 0.12936483$

$\alpha_f = 0.45253333$

$b = 250.00$

$h = 500.00$

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

$b_w = 250.00$

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

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\alpha_{se} ((5.4d), TBDY) = 0.03751166$

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$

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)

 $p_{sh,x} (5.4d) = 0.001848$

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 500.00$

$p_{sh,y} (5.4d) = 0.00369599$

Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

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

lo/lou,min = lb/lc = 0.30356779

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

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

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

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

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

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

lo/lou,min = lb/lc,min = 0.30356779

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

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

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

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

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257

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

lo/lou,min = lb/lc = 0.30356779

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

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764

2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764

v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401

and confined core properties:

b = 440.00
d = 177.00
d' = 13.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916
1 = $A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.16701987$
2 = $A_{s1,com}/(b*d)*(f_{s2}/f_c) = 0.16701987$
v = $A_{s1,mid}/(b*d)*(f_{sv}/f_c) = 0.08097933$

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

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

--->
su (4.9) = 0.25329952
Mu = MRc (4.14) = 5.9930E+007
u = su (4.1) = 3.4011160E-005

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.30356779

lb = 300.00

l_d = 988.2471

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

db = 18.00

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

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

K_{tr} = 4.61999

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 = 170.00

n = 8.00

Calculation of Mu1-

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

u = 3.4011160E-005

Mu = 5.9930E+007

with full section properties:

b = 500.00

d = 207.00

d' = 43.00

v = 0.00225456

N = 4666.932

f_c = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01464474

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

From (5.4b), TBDY: cu = 0.01464474

we ((5.4c), TBDY) = ase* sh,min*f_{ywe}/f_{ce}+ Min(fx, fy) = 0.07762821

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

fx = 0.07705054

af = 0.45253333

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.004064

bw = 500.00

effective stress from (A.35), ff,e = 837.9178

fy = 0.12936483

af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), pf = $2t_f/bw = 0.008128$
bw = 250.00
effective stress from (A.35), ff,e = 703.4155

R = 40.00
Effective FRP thickness, tf = $NL*t*\text{Cos}(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = $\text{Min}(psh,x, psh,y) = 0.001848$

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) = 0.001848
Ash = $\text{Astir}*ns = 78.53982$
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = $\text{Astir}*ns = 78.53982$
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

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

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764

2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764

v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401

and confined core properties:

b = 440.00

d = 177.00

d' = 13.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987

2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987

v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

su (4.9) = 0.25329952

Mu = MRc (4.14) = 5.9930E+007

u = su (4.1) = 3.4011160E-005

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.30356779

lb = 300.00

ld = 988.2471

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

= 1

db = 18.00

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

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 4.61999

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 = 170.00

n = 8.00

Calculation of Mu2+

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

u = 3.4011160E-005
Mu = 5.9930E+007

with full section properties:

b = 500.00

d = 207.00

d' = 43.00

v = 0.00225456

N = 4666.932

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01464474$

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

From (5.4b), TBDY: $cu = 0.01464474$

w_e ((5.4c), TBDY) = $ase * sh_{\min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.07762821$

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

fx = 0.07705054

af = 0.45253333

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

bw = 500.00

effective stress from (A.35), $ff_e = 837.9178$

fy = 0.12936483

af = 0.45253333

b = 250.00

h = 500.00

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

bw = 250.00

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

R = 40.00

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

ase ((5.4d), TBDY) = 0.03751166

bo = 440.00

ho = 190.00

bi2 = 459400.00

$psh_{\min} = \text{Min}(psh_x, psh_y) = 0.001848$

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) = 0.001848

Ash = $A_{stir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 500.00

psh_y (5.4d) = 0.00369599

Ash = $A_{stir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 250.00

s = 170.00

$fy_{we} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$

c = confinement factor = 1.13916

y1 = 0.00130695

sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.30356779$

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

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

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

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

with $fs_1 = fs = 313.6681$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00130695$

$sh_2 = 0.00451687$

$ft_2 = 376.4017$

$fy_2 = 313.6681$

$su_2 = 0.005257$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30356779$

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

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

with $fs_2 = fs = 313.6681$

with $Es_2 = Es = 200000.00$

$y_v = 0.00130695$

$sh_v = 0.00451687$

$ft_v = 376.4017$

$fy_v = 313.6681$

$suv = 0.005257$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.30356779$

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

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

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

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

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

with $fsv = fs = 313.6681$

with $Es_v = Es = 200000.00$

$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.1256764$

$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.1256764$

$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.06093401$

and confined core properties:

$b = 440.00$

$d = 177.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 22.78316$

$cc (5A.5, TBDY) = 0.00339158$

$c = \text{confinement factor} = 1.13916$

$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.16701987$

$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.16701987$

$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.08097933$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.25329952$

$Mu = MRc (4.14) = 5.9930E+007$

$u = su (4.1) = 3.4011160E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

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

$= 1$

$d_b = 18.00$

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

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

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

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

$s = 170.00$

$n = 8.00$

Calculation of μ_2 -

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

$\mu = 3.4011160E-005$

$\mu_u = 5.9930E+007$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00225456$

$N = 4666.932$

$f_c = 20.00$

c_o (5A.5, TBDY) = 0.002

Final value of μ_c : $\mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_c) = 0.01464474$

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

From (5.4b), TBDY: $\mu_c = 0.01464474$

we ((5.4c), TBDY) = $\text{ase} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$

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

$f_x = 0.07705054$

$\text{af} = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $\text{ffe} = 837.9178$

$f_y = 0.12936483$

$\text{af} = 0.45253333$

$b = 250.00$

$h = 500.00$

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

$bw = 250.00$

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

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

ase ((5.4d), TBDY) = 0.03751166

$b_o = 440.00$

$h_o = 190.00$

$$bi2 = 459400.00$$

$$psh,min = \text{Min}(psh,x, psh,y) = 0.001848$$

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)

$$psh,x (5.4d) = 0.001848$$

$$Ash = Astir*ns = 78.53982$$

$$\text{No stirrups, } ns = 2.00$$

$$bk = 500.00$$

$$psh,y (5.4d) = 0.00369599$$

$$Ash = Astir*ns = 78.53982$$

$$\text{No stirrups, } ns = 2.00$$

$$bk = 250.00$$

$$s = 170.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$

$$c = \text{confinement factor} = 1.13916$$

$$y1 = 0.00130695$$

$$sh1 = 0.00451687$$

$$ft1 = 376.4017$$

$$fy1 = 313.6681$$

$$su1 = 0.005257$$

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

$$lo/lou,min = lb/l_d = 0.30356779$$

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

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

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

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

$$\text{with } fs1 = fs = 313.6681$$

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

$$y2 = 0.00130695$$

$$sh2 = 0.00451687$$

$$ft2 = 376.4017$$

$$fy2 = 313.6681$$

$$su2 = 0.005257$$

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

$$lo/lou,min = lb/l_b,min = 0.30356779$$

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

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

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

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

$$\text{with } fs2 = fs = 313.6681$$

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

$$yv = 0.00130695$$

$$shv = 0.00451687$$

$$ftv = 376.4017$$

$$fyv = 313.6681$$

$$suv = 0.005257$$

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

$$lo/lou,min = lb/l_d = 0.30356779$$

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

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

with $f_{sv} = f_s = 313.6681$
with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1256764$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1256764$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.06093401$

and confined core properties:

$b = 440.00$
 $d = 177.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16701987$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.16701987$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08097933$

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

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

--->
 $su (4.9) = 0.25329952$
 $Mu = MRc (4.14) = 5.9930E+007$
 $u = su (4.1) = 3.4011160E-005$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.30356779$

$l_b = 300.00$
 $l_d = 988.2471$

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

$= 1$
 $db = 18.00$
Mean strength value of all re-bars: $f_y = 555.55$
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$
where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 265235.248$

Calculation of Shear Strength at edge 1, $V_{r1} = 265235.248$

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

$V_{Col0} = 265235.248$
 $k_{nl} = 1$ (zero step-static loading)

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

 $= 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $Mu = 2.3992784E-012$
 $Vu = 2.9007121E-031$
 $d = 0.8 * h = 200.00$
 $Nu = 4666.932$
 $Ag = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 49279.392$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 170.00$$

V_s is multiplied by $\text{Col} = 0.60$

$$s/d = 0.85$$

$$V_f \text{ ((11-3)-(11.4), ACI 440) } = 109072.851$$

$f = 0.95$, 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: $\theta = b_1 + 90^\circ = 90.00$

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

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

$$d_{fv} = d \text{ (figure 11.2, ACI 440) } = 207.00$$

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

$$E_f = 64828.00$$

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

with $f_u = 0.01$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 297085.704$$

$$b_w = 500.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 265235.248$

$$V_{r2} = V_{\text{Col}} \text{ ((10.3), ASCE 41-17) } = k_{nl} * V_{\text{Col}0}$$

$$V_{\text{Col}0} = 265235.248$$

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

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

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

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

$$M/Vd = 2.00$$

$$M_u = 2.3992784E-012$$

$$V_u = 2.9007121E-031$$

$$d = 0.8 * h = 200.00$$

$$N_u = 4666.932$$

$$A_g = 125000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 49279.392$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 170.00$$

V_s is multiplied by $\text{Col} = 0.60$

$$s/d = 0.85$$

$$V_f \text{ ((11-3)-(11.4), ACI 440) } = 109072.851$$

$f = 0.95$, 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: $\theta = b_1 + 90^\circ = 90.00$

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

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

$$d_{fv} = d \text{ (figure 11.2, ACI 440) } = 207.00$$

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

$$E_f = 64828.00$$

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

with $f_u = 0.01$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 297085.704$$

$$b_w = 500.00$$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

Section Height, $H = 250.00$
Section Width, $W = 500.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.13916
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, $V_a = 1.3558547E-031$
EDGE -B-
Shear Force, $V_b = -1.3558547E-031$
BOTH EDGES
Axial Force, $F = -4666.932$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{l,ten} = 829.3805$
-Compression: $As_{l,com} = 829.3805$
-Middle: $As_{l,mid} = 402.1239$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.23676754$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96937.922$

with

$M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 1.4541E+008$

$M_{u1+} = 1.4541E+008$, 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

$M_{u1-} = 1.4541E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 1.4541E+008$

$M_{u2+} = 1.4541E+008$, 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

$M_{u2-} = 1.4541E+008$, 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:

$\phi_u = 1.4467178E-005$

$M_u = 1.4541E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00204242$

$N = 4666.932$

$f_c = 20.00$

α_{co} (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$

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

From (5.4b), TBDY: $\phi_u = 0.01464474$

ϕ_{we} ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$

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

 $\phi_x = 0.07705054$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f/b_w = 0.004064$

$b_w = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$\phi_y = 0.12936483$

$\alpha_f = 0.45253333$

$b = 250.00$

$h = 500.00$

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

$b_w = 250.00$

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

$R = 40.00$

Effective FRP thickness, $t_f = N L * t * \text{Cos}(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

α_{se} ((5.4d), TBDY) = 0.03751166

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$\text{psh}_{\min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.001848$

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) = 0.001848
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

y2, sh2,ft2,fy2, are also multiplied by Min(1,1.25*(lb/lb,min)^ 2/3), from 10.3.5, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

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

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127

2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127

v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.1603292$$

$$2 = A_{s2,com}/(b*d)*(f_{s2}/f_c) = 0.1603292$$

$$v = A_{s,mid}/(b*d)*(f_{sv}/f_c) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.20486988$$

$$\mu_u = M_{Rc} (4.14) = 1.4541E+008$$

$$u = s_u (4.1) = 1.4467178E-005$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.30356779$

$$l_b = 300.00$$

$$l_d = 988.2471$$

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

$$= 1$$

$$d_b = 18.00$$

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

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

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

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of μ_u

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

$$u = 1.4467178E-005$$

$$\mu_u = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464474$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01464474$$

$$\text{we ((5.4c), TBDY) } = a_s e^* \text{ sh}_{, \min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

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

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

h = 250.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$
bw = 500.00
effective stress from (A.35), $ff,e = 837.9178$

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

R = 40.00
Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.001848
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) = 0.001848
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by $Min(1,1.25*(lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs1 = fs = 313.6681$
with $Es1 = Es = 200000.00$
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $es_{u2_nominal} = 0.08$,

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

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

with $fs_2 = fs = 313.6681$

with $Es_2 = Es = 200000.00$

$y_v = 0.00130695$

$sh_v = 0.00451687$

$ft_v = 376.4017$

$fy_v = 313.6681$

$s_{uv} = 0.005257$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$lo/lo_{u,min} = lb/d = 0.30356779$

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

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

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

For calculation of $es_{uv_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY.

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

with $fs_v = fs = 313.6681$

with $Es_v = Es = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.11385127$

2 = $As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.11385127$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.05520062$

and confined core properties:

$b = 190.00$

$d = 427.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 22.78316$

$cc (5A.5, TBDY) = 0.00339158$

$c = \text{confinement factor} = 1.13916$

1 = $As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.1603292$

2 = $As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.1603292$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.07773537$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$s_u (4.9) = 0.20486988$

$\mu_u = MR_c (4.14) = 1.4541E+008$

$u = s_u (4.1) = 1.4467178E-005$

Calculation of ratio lb/d

Lap Length: $lb/d = 0.30356779$

$lb = 300.00$

$ld = 988.2471$

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

= 1

$db = 18.00$

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

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 4.61999$

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

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

$s = 170.00$

$n = 8.00$

Calculation of Mu2+

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

$$\mu = 1.4467178E-005$$

$$Mu = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464474$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01464474$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

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

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s e \text{ ((5.4d), TBDY)} = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.001848$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00369599$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

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

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127

2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127

v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062

and confined core properties:

b = 190.00

d = 427.00

d' = 13.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1603292

2 = Asl,com/(b*d)*(fs2/fc) = 0.1603292

v = Asl,mid/(b*d)*(fsv/fc) = 0.07773537

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.20486988
Mu = MRc (4.14) = 1.4541E+008
u = su (4.1) = 1.4467178E-005

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.30356779

lb = 300.00

l_d = 988.2471

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

= 1

db = 18.00

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

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

K_{tr} = 4.61999

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 = 170.00

n = 8.00

Calculation of Mu₂-

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

u = 1.4467178E-005

Mu = 1.4541E+008

with full section properties:

b = 250.00

d = 457.00

d' = 43.00

v = 0.00204242

N = 4666.932

f_c = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01464474

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

From (5.4b), TBDY: cu = 0.01464474

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.07762821

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

fx = 0.07705054

af = 0.45253333

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.004064

bw = 500.00

effective stress from (A.35), ff,e = 837.9178

fy = 0.12936483

af = 0.45253333

b = 250.00

h = 500.00

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

bw = 250.00

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

R = 40.00

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

$f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase \text{ ((5.4d), TBDY)} = 0.03751166$
 $bo = 440.00$
 $ho = 190.00$
 $bi2 = 459400.00$

$psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.001848$
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)

 $psh_{,x} \text{ (5.4d)} = 0.001848$
 $A_{sh} = A_{stir} * n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $bk = 500.00$

 $psh_{,y} \text{ (5.4d)} = 0.00369599$
 $A_{sh} = A_{stir} * n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $bk = 250.00$

 $s = 170.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$

$y_1 = 0.00130695$
 $sh_1 = 0.00451687$
 $ft_1 = 376.4017$
 $fy_1 = 313.6681$
 $su_1 = 0.005257$

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

$lo/lo_{,min} = lb/ld = 0.30356779$

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

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

with $fs_1 = fs = 313.6681$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00130695$
 $sh_2 = 0.00451687$
 $ft_2 = 376.4017$
 $fy_2 = 313.6681$
 $su_2 = 0.005257$

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

$lo/lo_{,min} = lb/lb_{,min} = 0.30356779$

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

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

with $fs_2 = fs = 313.6681$

with $Es_2 = Es = 200000.00$

$y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $suv = 0.005257$

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

$lo/lo_{,min} = lb/ld = 0.30356779$

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

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

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

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

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

$$\text{with } fsv = fs = 313.6681$$

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.1603292$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.1603292$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

$$su (4.9) = 0.20486988$$

$$\text{Mu} = \text{MRc} (4.14) = 1.4541\text{E}+008$$

$$u = su (4.1) = 1.4467178\text{E}-005$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$

$$lb = 300.00$$

$$ld = 988.2471$$

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

$$= 1$$

$$db = 18.00$$

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

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$Ktr = 4.61999$$

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

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of Shear Strength $Vr = \text{Min}(Vr1, Vr2) = 409422.352$

Calculation of Shear Strength at edge 1, $Vr1 = 409422.352$

$$Vr1 = VCol ((10.3), ASCE 41-17) = knl * VCol0$$

$$VCol0 = 409422.352$$

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

NOTE: In expression (10-3) ' $Vs = Av * fy * d / s$ ' is replaced by ' $Vs + f * Vf$ '

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

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

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

$$M/Vd = 2.00$$

$\mu_u = 2.8180236E-013$
 $V_u = 1.3558547E-031$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 164264.64$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.425$
 V_f ((11-3)-(11.4), ACI 440) = 240803.347
 $f = 0.95$, 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: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 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: $V_s + V_f \leq 297085.704$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 409422.352$
 $V_{r2} = V_{\text{Col}}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{\text{Col}0}$
 $V_{\text{Col}0} = 409422.352$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$\mu_c = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 2.8180236E-013$
 $V_u = 1.3558547E-031$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 164264.64$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.425$
 V_f ((11-3)-(11.4), ACI 440) = 240803.347
 $f = 0.95$, 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: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 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: $V_s + V_f \leq 297085.704$
 $bw = 250.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
At local axis: 2
Integration Section: (b)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\phi = 1.00$
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$
Section Height, $H = 250.00$
Section Width, $W = 500.00$
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, $NoDir = 1$
Fiber orientations, $bi = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 3.8606651E-011$
Shear Force, $V_2 = 3085.676$
Shear Force, $V_3 = 2.2952864E-013$
Axial Force, $F = -4810.556$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{l,ten} = 829.3805$
-Compression: $As_{l,com} = 829.3805$
-Middle: $As_{l,mid} = 402.1239$
Mean Diameter of Tension Reinforcement, $Db_L = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $\phi_{u,R} = \phi_u = 0.00620875$

$$u = y + p = 0.00620875$$

- Calculation of y -

$$y = (M_y * L_s / 3) / E_{eff} = 0.00620875 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 5.0977E+007$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 1500.00$$

$$\text{From table 10.5, ASCE 41_17: } E_{eff} = \text{factor} * E_c * I_g = 4.1053E+012$$

$$\text{factor} = 0.30$$

$$A_g = 125000.00$$

$$f_c' = 20.00$$

$$N = 4810.556$$

$$E_c * I_g = 1.3684E+013$$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$$y_{ten} = 1.0451269E-005$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 291.1836$$

$$d = 207.00$$

$$y = 0.32702707$$

$$A = 0.02007155$$

$$B = 0.01218373$$

$$\text{with } p_t = 0.00801334$$

$$p_c = 0.00801334$$

$$p_v = 0.00388525$$

$$N = 4810.556$$

$$b = 500.00$$

$$" = 0.20772947$$

$$y_{comp} = 2.5958133E-005$$

$$\text{with } f_c' \text{ (12.3, (ACI 440))} = 20.44529$$

$$f_c = 20.00$$

$$f_l = 0.9425867$$

$$b = 500.00$$

$$h = 250.00$$

$$A_g = 125000.00$$

$$\text{From (12.9), ACI 440: } k_a = 0.1506892$$

$$g = p_t + p_c + p_v = 0.01991193$$

$$r_c = 40.00$$

$$A_e / A_c = 0.60275679$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(\theta_1) = 1.016$$

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

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 21019.039$$

$$y = 0.32584352$$

$$A = 0.0197792$$

$$B = 0.01202411$$

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

Calculation of ratio I_b / I_d

$$\text{Lap Length: } I_d / I_{d,min} = 0.37945973$$

$$I_b = 300.00$$

$$I_d = 790.5977$$

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

$$= 1$$

$$d_b = 18.00$$

$$\text{Mean strength value of all re-bars: } f_y = 444.44$$

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

t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 4.61999
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 = 170.00
n = 8.00

- Calculation of ρ -

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

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$
shear control ratio $V_y E / V_{CoI} E = 0.15063296$

d = 207.00

s = 0.00

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

$A_v = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$b_w = 500.00$

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 = 4810.556

$A_g = 125000.00$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.01991193$

b = 500.00

d = 207.00

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 7

column C1, Floor 1

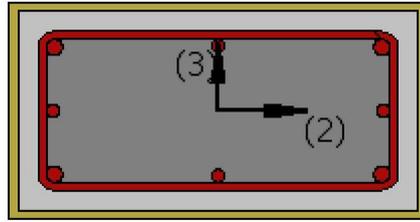
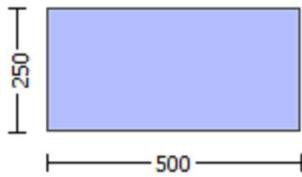
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

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, $M_a = 6.5063436E-010$

Shear Force, $V_a = -2.2952864E-013$

EDGE -B-

Bending Moment, $M_b = 3.8606651E-011$

Shear Force, $V_b = 2.2952864E-013$
 BOTH EDGES
 Axial Force, $F = -4810.556$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 0.00$
 -Compression: $As_c = 2060.885$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{t,ten} = 829.3805$
 -Compression: $As_{c,com} = 829.3805$
 -Middle: $As_{mid} = 402.1239$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 248574.19$
 V_n ((10.3), ASCE 41-17) = $k_n \phi V_{Col} = 248574.19$
 $V_{Col} = 248574.19$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.00$

NOTE: In expression (10-3) ' $V_s = A_v \phi_f y d / s$ ' is replaced by ' $V_s + \phi_f V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 $f'_c = 16.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 3.8606651E-011$
 $V_u = 2.2952864E-013$
 $d = 0.8 \cdot h = 200.00$
 $N_u = 4810.556$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 44351.896$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 170.00$

V_s is multiplied by $\phi_{Col} = 0.60$
 $s/d = 0.85$

V_f ((11-3)-(11.4), ACI 440) = 109072.851
 $\phi_f = 0.95$, 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 $V_f(\theta)$, is implemented for every different fiber orientation θ_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

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

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 207.00

ϕ_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$\phi_{fe} = 0.004$, from (11.6a), ACI 440

with $\phi_{fu} = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 265721.532$

$b_w = 500.00$

$displacement_ductility_demand$ is calculated as δ / y

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

From analysis, chord rotation $\theta = 2.1039935E-020$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00620875$ ((4.29), Biskinis Phd)

$M_y = 5.0977E+007$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 4.1053E+012$

factor = 0.30

$A_g = 125000.00$

$f_c' = 20.00$

$N = 4810.556$

$E_c * I_g = 1.3684E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$y_{ten} = 1.0451269E-005$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 291.1836$

$d = 207.00$

$y = 0.32702707$

$A = 0.02007155$

$B = 0.01218373$

with $p_t = 0.00801334$

$p_c = 0.00801334$

$p_v = 0.00388525$

$N = 4810.556$

$b = 500.00$

$" = 0.20772947$

$y_{comp} = 2.5958133E-005$

with $f_c' (12.3, (ACI 440)) = 20.44529$

$f_c = 20.00$

$f_l = 0.9425867$

$b = 500.00$

$h = 250.00$

$A_g = 125000.00$

From (12.9), ACI 440: $k_a = 0.1506892$

$g = p_t + p_c + p_v = 0.01991193$

$r_c = 40.00$

$A_e / A_c = 0.60275679$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 21019.039$

$y = 0.32584352$

$A = 0.0197792$

$B = 0.01202411$

with $E_s = 200000.00$

Calculation of ratio I_b / I_d

Lap Length: $I_d / I_d, \text{min} = 0.37945973$

$I_b = 300.00$

$I_d = 790.5977$

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

$= 1$

$d_b = 18.00$

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

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

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

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

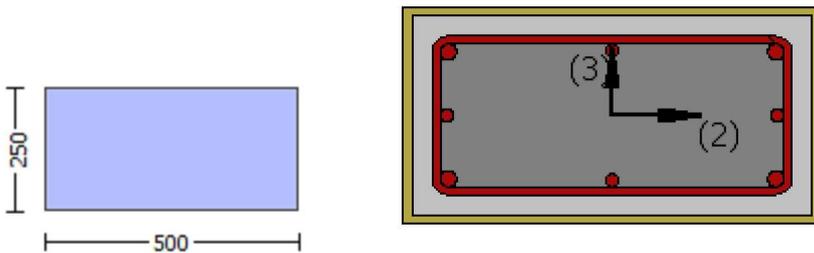
$s = 170.00$

n = 8.00

End Of Calculation of Shear Capacity for element: column C1 of floor 1
At local axis: 3
Integration Section: (b)

Calculation No. 8

column C1, Floor 1
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)
Analysis: Uniform +X
Check: Chord rotation capacity (θ)
Edge: End
Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At Shear local axis: 3
(Bending local axis: 2)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

Section Height, $H = 250.00$
Section Width, $W = 500.00$
Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916
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 = 2.9007121E-031
EDGE -B-
Shear Force, V_b = -2.9007121E-031
BOTH EDGES
Axial Force, F = -4666.932
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: A_{st} = 0.00
-Compression: A_{sc} = 2060.885
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten}$ = 829.3805
-Compression: $A_{st,com}$ = 829.3805
-Middle: $A_{st,mid}$ = 402.1239

Calculation of Shear Capacity ratio , V_e/V_r = 0.15063296
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 39953.171$
with
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 5.9930E+007$
 $\mu_{1+} = 5.9930E+007$, 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
 $\mu_{1-} = 5.9930E+007$, 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
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 5.9930E+007$
 $\mu_{2+} = 5.9930E+007$, 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
 $\mu_{2-} = 5.9930E+007$, 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:
 $\mu = 3.4011160E-005$
 $\mu_u = 5.9930E+007$

with full section properties:
 $b = 500.00$

d = 207.00

d' = 43.00

v = 0.00225456

N = 4666.932

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01464474$

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

From (5.4b), TBDY: $cu = 0.01464474$

we ((5.4c), TBDY) = $ase * sh_{\min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.07762821$

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

fx = 0.07705054

af = 0.45253333

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

bw = 500.00

effective stress from (A.35), $ff_e = 837.9178$

fy = 0.12936483

af = 0.45253333

b = 250.00

h = 500.00

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

bw = 250.00

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

R = 40.00

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

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = 0.03751166

bo = 440.00

ho = 190.00

bi2 = 459400.00

psh,min = $\text{Min}(psh_x, psh_y) = 0.001848$

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) = 0.001848

Ash = $A_{stir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 500.00

psh,y (5.4d) = 0.00369599

Ash = $A_{stir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 250.00

s = 170.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$

c = confinement factor = 1.13916

y1 = 0.00130695

sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

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

lo/lou,min = $lb/d = 0.30356779$

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

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

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

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

with $fs1 = fs = 313.6681$

with $Es1 = Es = 200000.00$

$y2 = 0.00130695$

$sh2 = 0.00451687$

$ft2 = 376.4017$

$fy2 = 313.6681$

$su2 = 0.005257$

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

$lo/lo_{min} = lb/lb_{min} = 0.30356779$

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

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

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

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

with $fs2 = fs = 313.6681$

with $Es2 = Es = 200000.00$

$yv = 0.00130695$

$shv = 0.00451687$

$ftv = 376.4017$

$fyv = 313.6681$

$suv = 0.005257$

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

$lo/lo_{min} = lb/ld = 0.30356779$

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

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

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

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

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

with $fsv = fs = 313.6681$

with $Esv = Es = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (fs1/fc) = 0.1256764$

2 = $Asl_{com}/(b \cdot d) \cdot (fs2/fc) = 0.1256764$

v = $Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.06093401$

and confined core properties:

$b = 440.00$

$d = 177.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 22.78316$

$cc (5A.5, TBDY) = 0.00339158$

c = confinement factor = 1.13916

1 = $Asl_{ten}/(b \cdot d) \cdot (fs1/fc) = 0.16701987$

2 = $Asl_{com}/(b \cdot d) \cdot (fs2/fc) = 0.16701987$

v = $Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.08097933$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.25329952$

$\mu_u = MR_c (4.14) = 5.9930E+007$

$u = su (4.1) = 3.4011160E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$

$lb = 300.00$

$ld = 988.2471$

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

= 1

db = 18.00

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

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 4.61999

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

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

s = 170.00

n = 8.00

Calculation of μ_1 -

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

$\mu = 3.4011160E-005$

$\mu_u = 5.9930E+007$

with full section properties:

b = 500.00

d = 207.00

d' = 43.00

v = 0.00225456

N = 4666.932

$f_c = 20.00$

α (5A.5, TBDY) = 0.002

Final value of μ_c : $\mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01464474$

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

From (5.4b), TBDY: $\mu_c = 0.01464474$

μ_{ve} ((5.4c), TBDY) = $\alpha s_e * \text{sh}_{\min} * f_{yve} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$

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

 $f_x = 0.07705054$

$\alpha f = 0.45253333$

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.004064$

$b_w = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

 $f_y = 0.12936483$

$\alpha f = 0.45253333$

b = 250.00

h = 500.00

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

$b_w = 250.00$

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

R = 40.00

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

αs_e ((5.4d), TBDY) = 0.03751166

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$

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) = 0.001848
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

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

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

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

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

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

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

y2, sh2,ft2,fy2, are also multiplied by Min(1,1.25*(lb/lb,min)^ 2/3), from 10.3.5, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

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

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

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

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

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764
2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764
v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.16701987$$

$$2 = A_{s2,com}/(b*d)*(f_{s2}/f_c) = 0.16701987$$

$$v = A_{s,mid}/(b*d)*(f_{sv}/f_c) = 0.08097933$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.25329952$$

$$M_u = M_{Rc} (4.14) = 5.9930E+007$$

$$u = s_u (4.1) = 3.4011160E-005$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.30356779$

$$l_b = 300.00$$

$$l_d = 988.2471$$

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

$$= 1$$

$$d_b = 18.00$$

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

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

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

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of M_u2+

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

$$u = 3.4011160E-005$$

$$M_u = 5.9930E+007$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00225456$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464474$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01464474$$

$$w_e ((5.4c), TBDY) = a_s e^* s_{h, \min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

h = 250.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$
bw = 500.00
effective stress from (A.35), $ff,e = 837.9178$

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

R = 40.00
Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.001848
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) = 0.001848
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by $Min(1,1.25*(lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs1 = fs = 313.6681$
with $Es1 = Es = 200000.00$
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $es_{u2_nominal} = 0.08$,

For calculation of $es_{u2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fs_{y2} = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 313.6681$

with $Es_2 = Es = 200000.00$

$y_v = 0.00130695$

$sh_v = 0.00451687$

$ft_v = 376.4017$

$fy_v = 313.6681$

$s_{uv} = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$lo/lou, \min = lb/d = 0.30356779$

$s_{uv} = 0.4 \cdot es_{uv_nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,

considering characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY

For calculation of $es_{uv_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_v = fs = 313.6681$

with $Es_v = Es = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.1256764$

2 = $As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.1256764$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.06093401$

and confined core properties:

$b = 440.00$

$d = 177.00$

$d' = 13.00$

f_{cc} (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = $As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.16701987$

2 = $As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.16701987$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.08097933$

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) = 0.25329952

$\mu_u = MR_c$ (4.14) = 5.9930E+007

$u = s_u$ (4.1) = 3.4011160E-005

Calculation of ratio lb/d

Lap Length: $lb/d = 0.30356779$

$lb = 300.00$

$ld = 988.2471$

Calculation of lb, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$

where $A_{tr,x}, A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis

$s = 170.00$

$n = 8.00$

Calculation of Mu2-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 3.4011160E-005$$

$$Mu = 5.9930E+007$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00225456$$

$$N = 4666.932$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_c) = 0.01464474$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.01464474$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.001848$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00369599$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687

ft2 = 376.4017

fy2 = 313.6681

su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695
shv = 0.00451687

ftv = 376.4017

fyv = 313.6681

suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764

2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764

v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401

and confined core properties:

b = 440.00

d = 177.00

d' = 13.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987

2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987

v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.25329952
Mu = MRc (4.14) = 5.9930E+007
u = su (4.1) = 3.4011160E-005

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.30356779

lb = 300.00

ld = 988.2471

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 20.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 4.61999

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 = 170.00

n = 8.00

Calculation of Shear Strength Vr = Min(Vr1, Vr2) = 265235.248

Calculation of Shear Strength at edge 1, Vr1 = 265235.248

Vr1 = VCol ((10.3), ASCE 41-17) = knl*VCol0

VCol0 = 265235.248

knl = 1 (zero step-static loading)

NOTE: In expression (10-3) 'Vs = Av*fy*d/s' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

fc' = 20.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/d = 2.00

Mu = 2.3992784E-012

Vu = 2.9007121E-031

d = 0.8*h = 200.00

Nu = 4666.932

Ag = 125000.00

From (11.5.4.8), ACI 318-14: Vs = 49279.392

Av = 157079.633

fy = 444.44

s = 170.00

Vs is multiplied by Col = 0.60

s/d = 0.85

Vf ((11-3)-(11.4), ACI 440) = 109072.851

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 + cota)sina which is more a generalised expression,

where is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(,), is implemented for every different fiber orientation ai, as well as for 2 crack directions, = 45° and = -45° to take into consideration the cyclic seismic loading.

orientation 1: 1 = b1 + 90° = 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) = 207.00

ffe ((11-5), ACI 440) = 259.312

Ef = 64828.00

fe = 0.004, from (11.6a), ACI 440

with fu = 0.01

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $bw = 500.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 265235.248$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l * V_{Col0}$
 $V_{Col0} = 265235.248$
 $k_n l = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M / V d = 2.00$
 $\mu_u = 2.3992784E-012$
 $\nu_u = 2.9007121E-031$
 $d = 0.8 * h = 200.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 49279.392$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$

V_s is multiplied by $\phi_{col} = 0.60$
 $s / d = 0.85$

V_f ((11-3)-(11.4), ACI 440) = 109072.851
 $f = 0.95$, 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: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \alpha_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 207.00

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: $V_s + V_f \leq 297085.704$
 $bw = 500.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\phi = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

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, $V_a = 1.3558547E-031$

EDGE -B-

Shear Force, $V_b = -1.3558547E-031$

BOTH EDGES

Axial Force, $F = -4666.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 829.3805$

-Compression: $A_{sl,com} = 829.3805$

-Middle: $A_{sl,mid} = 402.1239$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.23676754$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96937.922$

with

$M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 1.4541E+008$

$\mu_{u1+} = 1.4541E+008$, 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

$\mu_{u1-} = 1.4541E+008$, 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

$M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 1.4541E+008$

$\mu_{u2+} = 1.4541E+008$, 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

$\mu_{u2-} = 1.4541E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of μ_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.4467178E-005$$

$$\mu = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

$$\omega (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01464474$$

$$\omega_e ((5.4c), \text{TBDY}) = a_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$$

where $\phi = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A 4.4.3(6), } p_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$\phi_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A 4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t^* \text{Cos}(\beta_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} ((5.4d), \text{TBDY}) = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$$

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)

$$p_{sh,x} (5.4d) = 0.001848$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} (5.4d) = 0.00369599$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00130695$$

$$sh_1 = 0.00451687$$

$$ft_1 = 376.4017$$

$$fy_1 = 313.6681$$

$$su_1 = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_d = 0.30356779$$

$$s_u1 = 0.4 * e_{s1,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s1,nominal} = 0.08$,

For calculation of $e_{s1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $f_{s1} = f_s/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s1} = f_s = 313.6681$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.00130695$$

$$sh_2 = 0.00451687$$

$$ft_2 = 376.4017$$

$$fy_2 = 313.6681$$

$$s_u2 = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_{b,min} = 0.30356779$$

$$s_u2 = 0.4 * e_{s2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s2,nominal} = 0.08$,

For calculation of $e_{s2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $f_{s2} = f_s/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s2} = f_s = 313.6681$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.00130695$$

$$sh_v = 0.00451687$$

$$ft_v = 376.4017$$

$$fy_v = 313.6681$$

$$s_{u,v} = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_d = 0.30356779$$

$$s_{u,v} = 0.4 * e_{s_{u,v},nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s_{u,v},nominal} = 0.08$,

considering characteristic value $f_{s_{u,v}} = f_{sv}/1.2$, from table 5.1, TBDY
For calculation of $e_{s_{u,v},nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $f_{s_{u,v}} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{sv} = f_s = 313.6681$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.11385127$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.11385127$$

$$v = A_{s1,mid}/(b*d) * (f_{sv}/f_c) = 0.05520062$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 22.78316$$

$$c_c (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.1603292$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.1603292$$

$$v = A_{s1,mid}/(b*d) * (f_{sv}/f_c) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.20486988$$

$$\mu_u = M_{Rc} (4.14) = 1.4541E+008$$

$$u = s_u (4.1) = 1.4467178E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 170.00$

$n = 8.00$

Calculation of μ_{u1}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$\mu_u = 1.4467178E-005$

$\mu_u = 1.4541E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00204242$

$N = 4666.932$

$f_c = 20.00$

α (5A.5, TBDY) = 0.002

Final value of μ_u : $\mu_u^* = \text{shear_factor} * \max(\mu_u, \mu_c) = 0.01464474$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_u = 0.01464474$

where ((5.4c), TBDY) = $\alpha * \text{sh}_{\min} * f_{ywe}/f_{ce} + \min(f_x, f_y) = 0.07762821$

where $f = \alpha * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.07705054$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$

$\alpha_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

α_{se} ((5.4d), TBDY) = 0.03751166

$b_o = 440.00$

ho = 190.00

bi2 = 459400.00

psh,min = Min(psh,x , psh,y) = 0.001848

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) = 0.001848

Ash = Astir*ns = 78.53982

No stirups, ns = 2.00

bk = 500.00

psh,y (5.4d) = 0.00369599

Ash = Astir*ns = 78.53982

No stirups, ns = 2.00

bk = 250.00

s = 170.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158

c = confinement factor = 1.13916

y1 = 0.00130695

sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695

sh2 = 0.00451687

ft2 = 376.4017

fy2 = 313.6681

su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695

shv = 0.00451687

ftv = 376.4017

fyv = 313.6681

suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered

characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 313.6681$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.11385127$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.11385127$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.05520062$

and confined core properties:

$b = 190.00$

$d = 427.00$

$d' = 13.00$

$f_{cc} \text{ (5A.2, TBDY)} = 22.78316$

$cc \text{ (5A.5, TBDY)} = 0.00339158$

$c = \text{confinement factor} = 1.13916$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.1603292$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.1603292$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.07773537$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$su \text{ (4.9)} = 0.20486988$

$Mu = MRc \text{ (4.14)} = 1.4541E+008$

$u = su \text{ (4.1)} = 1.4467178E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$

$lb = 300.00$

$ld = 988.2471$

Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

$s = 170.00$

$n = 8.00$

Calculation of Mu_{2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 1.4467178E-005$

$Mu = 1.4541E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00204242$

$N = 4666.932$

$f_c = 20.00$

$co \text{ (5A.5, TBDY)} = 0.002$

Final value of cu : $cu^* = \text{shear_factor} \cdot \text{Max}(cu, cc) = 0.01464474$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01464474$

w_e ((5.4c), TBDY) = $a_{se} \cdot sh_{min} \cdot f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$
where $f = a_f \cdot p_f \cdot f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.07705054$
 $a_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$
From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.004064$
 $bw = 500.00$
effective stress from (A.35), $f_{f,e} = 837.9178$

$f_y = 0.12936483$
 $a_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$
From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.008128$
 $bw = 250.00$
effective stress from (A.35), $f_{f,e} = 703.4155$

$R = 40.00$
Effective FRP thickness, $t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 a_{se} ((5.4d), TBDY) = 0.03751166
 $b_o = 440.00$
 $h_o = 190.00$
 $b_{i2} = 459400.00$
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$
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) = 0.001848
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $b_k = 500.00$

$p_{sh,y}$ (5.4d) = 0.00369599
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $b_k = 250.00$

$s = 170.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$
From ((5.A5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $y_1 = 0.00130695$
 $sh_1 = 0.00451687$
 $ft_1 = 376.4017$
 $fy_1 = 313.6681$
 $su_1 = 0.005257$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30356779$
 $su_1 = 0.4 \cdot esu_{1,nominal}$ ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$
For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs_1 = fs = 313.6681$
with $Es_1 = Es = 200000.00$
 $y_2 = 0.00130695$
 $sh_2 = 0.00451687$
 $ft_2 = 376.4017$
 $fy_2 = 313.6681$

$$su_2 = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.30356779$$

$$su_2 = 0.4 * esu_2,nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu_2,nominal = 0.08,

For calculation of esu_2,nominal and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 313.6681$$

$$\text{with } Es_2 = Es = 200000.00$$

$$yv = 0.00130695$$

$$shv = 0.00451687$$

$$ftv = 376.4017$$

$$fyv = 313.6681$$

$$suv = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.30356779$$

$$suv = 0.4 * esuv,nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esuv,nominal = 0.08,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of esuv,nominal and yv, shv, ftv, fyv , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 313.6681$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.1603292$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.1603292$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs,y_2$ - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.20486988$$

$$\text{Mu} = \text{MRc} (4.14) = 1.4541\text{E}+008$$

$$u = su (4.1) = 1.4467178\text{E}-005$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$

$$lb = 300.00$$

$$ld = 988.2471$$

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$db = 18.00$$

Mean strength value of all re-bars: $fy = 555.55$

$fc' = 20.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$Ktr = 4.61999$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 170.00$$

$$n = 8.00$$

Calculation of μ_2 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.4467178E-005$$

$$\mu_2 = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

$$c_0 \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_c: \mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01464474$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_c = 0.01464474$$

$$\mu_{cc} \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(\beta_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,\text{min}} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.001848$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00369599$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$s = 170.00$
 $fy_{we} = 555.55$
 $f_{ce} = 20.00$
 From ((5.A.5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $y_1 = 0.00130695$
 $sh_1 = 0.00451687$
 $ft_1 = 376.4017$
 $fy_1 = 313.6681$
 $su_1 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 0.30356779$
 $su_1 = 0.4 * esu_1 \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esu_1 \text{ nominal} = 0.08$,
 For calculation of $esu_1 \text{ nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 313.6681$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.00130695$
 $sh_2 = 0.00451687$
 $ft_2 = 376.4017$
 $fy_2 = 313.6681$
 $su_2 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/lb, \min = 0.30356779$
 $su_2 = 0.4 * esu_2 \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esu_2 \text{ nominal} = 0.08$,
 For calculation of $esu_2 \text{ nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 313.6681$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 0.30356779$
 $suv = 0.4 * esuv \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esuv \text{ nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv \text{ nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 313.6681$
 with $Esv = Es = 200000.00$
 $1 = Asl, \text{ten}/(b * d) * (fs_1/fc) = 0.11385127$
 $2 = Asl, \text{com}/(b * d) * (fs_2/fc) = 0.11385127$
 $v = Asl, \text{mid}/(b * d) * (fsv/fc) = 0.05520062$
 and confined core properties:
 $b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $f_{cc} \text{ (5A.2, TBDY)} = 22.78316$
 $cc \text{ (5A.5, TBDY)} = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl, \text{ten}/(b * d) * (fs_1/fc) = 0.1603292$
 $2 = Asl, \text{com}/(b * d) * (fs_2/fc) = 0.1603292$

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u(4.9) = 0.20486988$$

$$\mu = M_{Rc}(4.14) = 1.4541E+008$$

$$u = s_u(4.1) = 1.4467178E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$$l_b = 300.00$$

$$l_d = 988.2471$$

Calculation of l_b, min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 170.00$$

$$n = 8.00$$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 409422.352$

Calculation of Shear Strength at edge 1, $V_{r1} = 409422.352$

$$V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} \cdot V_{Col0}$$

$$V_{Col0} = 409422.352$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$\mu = 2.8180236E-013$$

$$V_u = 1.3558547E-031$$

$$d = 0.8 \cdot h = 400.00$$

$$N_u = 4666.932$$

$$A_g = 125000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 164264.64$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 170.00$$

$$V_s \text{ is multiplied by } C_{ol} = 1.00$$

$$s/d = 0.425$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 240803.347$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$$w_f/s_f = 1 \text{ (FRP strips adjacent to one another).}$$

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.

$$\text{orientation 1: } \theta = b_1 + 90^\circ = 90.00$$

$$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|), \text{ with:}$$

total thickness per orientation, $tf1 = NL*t/NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 457.00
 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: $Vs + Vf <= 297085.704$
 $bw = 250.00$

Calculation of Shear Strength at edge 2, $Vr2 = 409422.352$
 $Vr2 = VCol$ ((10.3), ASCE 41-17) = $knl*VColO$
 $VColO = 409422.352$
 $knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $Vs = Av*fy*d/s$ ' is replaced by ' $Vs+ f*VF$ '
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 $fc' = 20.00$, but $fc^{0.5} <= 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $Mu = 2.8180236E-013$
 $Vu = 1.3558547E-031$
 $d = 0.8*h = 400.00$
 $Nu = 4666.932$
 $Ag = 125000.00$
From (11.5.4.8), ACI 318-14: $Vs = 164264.64$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 170.00$

Vs is multiplied by $Col = 1.00$
 $s/d = 0.425$

Vf ((11-3)-(11.4), ACI 440) = 240803.347
 $f = 0.95$, for fully-wrapped sections

$wf/sf = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $Vf(\theta, a)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, a1)|)$, with:

total thickness per orientation, $tf1 = NL*t/NoDir = 1.016$

$dfv = d$ (figure 11.2, ACI 440) = 457.00

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: $Vs + Vf <= 297085.704$

$bw = 250.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
At local axis: 3
Integration Section: (b)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Section Height, $H = 250.00$

Section Width, $W = 500.00$

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, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 76808.128$

Shear Force, $V_2 = 3085.676$

Shear Force, $V_3 = 2.2952864E-013$

Axial Force, $F = -4810.556$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 829.3805$

-Compression: $A_{sl,com} = 829.3805$

-Middle: $A_{sl,mid} = 402.1239$

Mean Diameter of Tension Reinforcement, $Db_L = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $\phi_{u,R} = \phi_u = 0.00069628$

$\phi_u = \phi_y + \phi_p = 0.00069628$

- Calculation of ϕ_y -

$\phi_y = (M_y * L_s / 3) / E_{eff} = 0.00069628$ ((4.29), Biskinis Phd)

$M_y = 1.1434E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.6421E+013$

factor = 0.30

$A_g = 125000.00$

$f_c' = 20.00$

$N = 4810.556$

$E_c * I_g = 5.4737E+013$

Calculation of Yielding Moment M_y

Calculation of ϕ_y and M_y according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 4.5287315\text{E}-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25*f_y*(l_b/l_d)^{2/3}) = 291.1836$
 $d = 457.00$
 $y = 0.29653227$
 $A = 0.01818298$
 $B = 0.01001242$
 with $pt = 0.00725935$
 $pc = 0.00725935$
 $pv = 0.00351968$
 $N = 4810.556$
 $b = 250.00$
 $" = 0.0940919$
 $y_{\text{comp}} = 1.2979423\text{E}-005$
 with $fc^* (12.3, (ACI 440)) = 20.44585$
 $fc = 20.00$
 $fl = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $Ag = 125000.00$
 From (12.9), ACI 440: $ka = 0.15087868$
 $g = pt + pc + pv = 0.01803838$
 $rc = 40.00$
 $Ae/Ac = 0.60351471$
 Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
 effective strain from (12.5) and (12.12), $efe = 0.004$
 $fu = 0.01$
 $Ef = 64828.00$
 $Ec = 21019.039$
 $y = 0.29518426$
 $A = 0.01791814$
 $B = 0.00986782$
 with $Es = 200000.00$

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_d, \text{min} = 0.37945973$
 $l_b = 300.00$
 $l_d = 790.5977$
 Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $f_y = 444.44$
 $fc' = 20.00$, but $fc^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

- Calculation of p -

From table 10-8: $p = 0.00$
 with:
 - Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
 shear control ratio $V_y E/V_{CoIOE} = 0.23676754$
 $d = 457.00$
 $s = 0.00$
 $t = A_v/(b_w*s) + 2*tf/b_w*(ffe/fs) = 0.00$

$A_v = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$b_w = 250.00$

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ is implemented to account for FRP contribution

where $f = 2 \cdot t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

$N_{UD} = 4810.556$

$A_g = 125000.00$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.01803838$

$b = 250.00$

$d = 457.00$

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (b)

Calculation No. 9

column C1, Floor 1

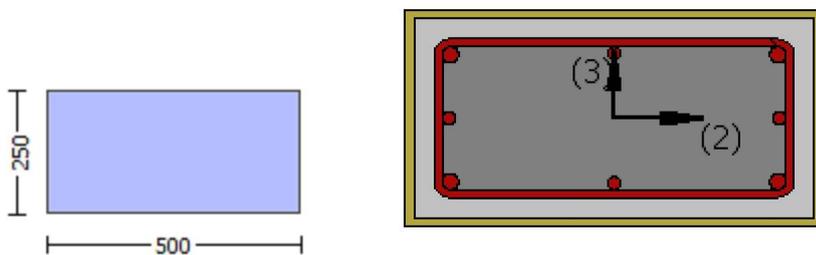
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcrs

Constant Properties

Knowledge Factor, = 1.00

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of μ for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE41-17).
Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

Section Height, $H = 250.00$
Section Width, $W = 500.00$
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, $M_a = -1.4246E+007$
Shear Force, $V_a = -4708.27$
EDGE -B-
Bending Moment, $M_b = 117197.472$
Shear Force, $V_b = 4708.27$
BOTH EDGES
Axial Force, $F = -4886.081$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 1231.504$
-Compression: $A_{sl,c} = 829.3805$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 829.3805$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 402.1239$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 316030.554$
 $V_n ((10.3), ASCE 41-17) = k_n \phi V_{CoI} = 316030.554$
 $V_{CoI} = 316030.554$
 $k_n = 1.00$
displacement_ductility_demand = 0.03495173

NOTE: In expression (10-3) ' $V_s = A_v \phi f_y \cdot d / s$ ' is replaced by ' $V_s + \phi V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 1.4246E+007$
 $V_u = 4708.27$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4886.081$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 147839.654$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.425$
 V_f ((11-3)-(11.4), ACI 440) = 240803.347
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = 45^\circ$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_{fe} = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 265721.532$
 $b_w = 250.00$

displacement_ductility_demand is calculated as δ / y

- Calculation of δ / y for END A -
for rotation axis 3 and integ. section (a)

From analysis, chord rotation $\theta = 0.00024547$
 $y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00702323$ ((4.29), Biskinis Phd)
 $M_y = 1.1435E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 3025.674
 From table 10.5, ASCE 41_17: $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 1.6421E+013$
 factor = 0.30
 $A_g = 125000.00$
 $f_c' = 20.00$
 $N = 4886.081$
 $E_c \cdot I_g = 5.4737E+013$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 4.5289398E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 291.1836$
 $d = 457.00$
 $y = 0.29656463$
 $A = 0.01818525$
 $B = 0.01001469$
 with $p_t = 0.00725935$
 $p_c = 0.00725935$
 $p_v = 0.00351968$

N = 4886.081
b = 250.00
" = 0.0940919
y_comp = 1.2978922E-005
with f_c^* (12.3, (ACI 440)) = 20.44585
f_c = 20.00
f_l = 0.9425867
b = 250.00
h = 500.00
A_g = 125000.00
From (12.9), ACI 440: $k_a = 0.15087868$
g = p_t + p_c + p_v = 0.01803838
r_c = 40.00
A_e/A_c = 0.60351471
Effective FRP thickness, t_f = NL*t*cos(b1) = 1.016
effective strain from (12.5) and (12.12), e_f_e = 0.004
f_u = 0.01
E_f = 64828.00
E_c = 21019.039
y = 0.29519565
A = 0.01791625
B = 0.00986782
with E_s = 200000.00

Calculation of ratio l_b/l_d

Lap Length: l_d/l_d,min = 0.37945973

l_b = 300.00

l_d = 790.5977

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: f_y = 444.44

f_c' = 20.00, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

K_tr = 4.61999

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 = 170.00

n = 8.00

End Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 10

column C1, Floor 1

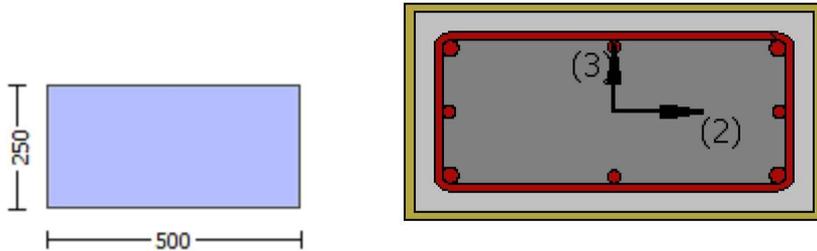
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_u)

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

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, Va = 2.9007121E-031
EDGE -B-
Shear Force, Vb = -2.9007121E-031
BOTH EDGES
Axial Force, F = -4666.932
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 2060.885
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 829.3805
-Compression: Asl,com = 829.3805
-Middle: Asl,mid = 402.1239

Calculation of Shear Capacity ratio , $V_e/V_r = 0.15063296$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 39953.171$
with
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 5.9930E+007$
 $Mu_{1+} = 5.9930E+007$, 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
 $Mu_{1-} = 5.9930E+007$, 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
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 5.9930E+007$
 $Mu_{2+} = 5.9930E+007$, 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
 $Mu_{2-} = 5.9930E+007$, 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:
 $\phi_u = 3.4011160E-005$
 $Mu = 5.9930E+007$

with full section properties:

b = 500.00
d = 207.00
d' = 43.00
v = 0.00225456
N = 4666.932
fc = 20.00
co (5A.5, TBDY) = 0.002
Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_u = 0.01464474$
 ϕ_u ((5.4c), TBDY) = $\phi_u^* * \text{sh}_{\text{min}} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$
where $\phi = \phi^* * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.07705054$
 $\phi_y = 0.45253333$
b = 500.00
h = 250.00
From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.004064$

bw = 500.00
effective stress from (A.35), $f_{f,e} = 837.9178$

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $f_{f,e} = 703.4155$

R = 40.00
Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00

psh,min = Min(psh,x , psh,y) = 0.001848
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) = 0.001848
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $Min(1, 1.25*(lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 313.6681$

with $Es1 = Es = 200000.00$

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered

characteristic value $f_{s2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s2} = f_s = 313.6681$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.00130695$

$sh_v = 0.00451687$

$ft_v = 376.4017$

$f_{yv} = 313.6681$

$s_{uv} = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30356779$

$s_{uv} = 0.4 \cdot e_{suv,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv,nominal}$ and y_v, sh_v, ft_v, f_{yv} , it is considered

characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 313.6681$

with $E_{sv} = E_s = 200000.00$

1 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.1256764$

2 = $A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.1256764$

v = $A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.06093401$

and confined core properties:

b = 440.00

d = 177.00

d' = 13.00

$f_{cc} (5A.2, TBDY) = 22.78316$

$cc (5A.5, TBDY) = 0.00339158$

c = confinement factor = 1.13916

1 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.16701987$

2 = $A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.16701987$

v = $A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08097933$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$s_u (4.9) = 0.25329952$

$M_u = M_{Rc} (4.14) = 5.9930E+007$

$u = s_u (4.1) = 3.4011160E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

s = 170.00

n = 8.00

Calculation of μ_1 -

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 3.4011160E-005$$

$$\mu = 5.9930E+007$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00225456$$

$$N = 4666.932$$

$$f_c = 20.00$$

$$\alpha_{co} \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01464474$$

$$\phi_{we} \text{ ((5.4c), TBDY)} = \alpha_{se} * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$$

where $\phi = \alpha_f * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.07705054$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 837.9178$$

$$\phi_y = 0.12936483$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TBDY)} = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$\text{psh}_{, \text{min}} = \text{Min}(\text{psh}_{,x}, \text{psh}_{,y}) = 0.001848$$

Expression ((5.4d), TBDY) for $\text{psh}_{, \text{min}}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\text{psh}_{,x} \text{ (5.4d)} = 0.001848$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$\text{psh}_{,y} \text{ (5.4d)} = 0.00369599$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y1 = 0.00130695$$

$$\text{sh}_1 = 0.00451687$$

$$ft1 = 376.4017$$

$$fy1 = 313.6681$$

$$su1 = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/l_d = 0.30356779$$

$$su1 = 0.4 * esu1_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 313.6681$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00130695$$

$$sh2 = 0.00451687$$

$$ft2 = 376.4017$$

$$fy2 = 313.6681$$

$$su2 = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/l_{b,min} = 0.30356779$$

$$su2 = 0.4 * esu2_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and $y2, sh2, ft2, fy2$, it is considered
characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 313.6681$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00130695$$

$$shv = 0.00451687$$

$$ftv = 376.4017$$

$$fyv = 313.6681$$

$$suv = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/l_d = 0.30356779$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

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 $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 313.6681$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl_{ten}/(b*d) * (fs1/fc) = 0.1256764$$

$$2 = Asl_{com}/(b*d) * (fs2/fc) = 0.1256764$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.06093401$$

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = Asl_{ten}/(b*d) * (fs1/fc) = 0.16701987$$

$$2 = Asl_{com}/(b*d) * (fs2/fc) = 0.16701987$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.08097933$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs, y2$ - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.25329952$$

$$Mu = MRc (4.14) = 5.9930E+007$$

$$u = s_u(4.1) = 3.4011160E-005$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.30356779$

$$l_b = 300.00$$

$$d = 988.2471$$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 170.00$$

$$n = 8.00$$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$u = 3.4011160E-005$$

$$\mu = 5.9930E+007$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00225456$$

$$N = 4666.932$$

$$f_c = 20.00$$

$$c_o(5A.5, \text{ TBDY}) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464474$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01464474$$

$$w_e((5.4c), \text{ TBDY}) = a_s e^* s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

u,f = 0.015

ase ((5.4d), TBDY) = 0.03751166

bo = 440.00

ho = 190.00

bi2 = 459400.00

psh,min = Min(psh,x , psh,y) = 0.001848

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) = 0.001848

Ash = Astir*ns = 78.53982

No stirrups, ns = 2.00

bk = 500.00

psh,y (5.4d) = 0.00369599

Ash = Astir*ns = 78.53982

No stirrups, ns = 2.00

bk = 250.00

s = 170.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158

c = confinement factor = 1.13916

y1 = 0.00130695

sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695

sh2 = 0.00451687

ft2 = 376.4017

fy2 = 313.6681

su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695

shv = 0.00451687

ftv = 376.4017

fyv = 313.6681

suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv_nominal}$ and y_v , sh_v, ft_v, 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, ASCE41-17.

with $f_{sv} = f_s = 313.6681$

with $E_{sv} = E_s = 200000.00$

$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.1256764$

$2 = A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.1256764$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.06093401$

and confined core properties:

$b = 440.00$

$d = 177.00$

$d' = 13.00$

f_{cc} (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

$c =$ confinement factor = 1.13916

$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.16701987$

$2 = A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.16701987$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08097933$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.25329952

$Mu = MRc$ (4.14) = 5.9930E+007

$u = su$ (4.1) = 3.4011160E-005

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

$s = 170.00$

$n = 8.00$

Calculation of Mu_2 -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 3.4011160E-005$

$Mu = 5.9930E+007$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00225456$

$N = 4666.932$

$f_c = 20.00$

co (5A.5, TBDY) = 0.002

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464474$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.01464474$

w_e ((5.4c), TBDY) = $ase * sh_{\min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07705054$

$af = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{f,e} = 837.9178$

 $f_y = 0.12936483$

$af = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{f,e} = 703.4155$

 $R = 40.00$

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

ase ((5.4d), TBDY) = 0.03751166

$bo = 440.00$

$ho = 190.00$

$bi2 = 459400.00$

$psh_{\min} = \text{Min}(psh_x, psh_y) = 0.001848$

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) = 0.001848

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$bk = 500.00$

 psh_y (5.4d) = 0.00369599

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$bk = 250.00$

 $s = 170.00$

$fy_{we} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$

$c = \text{confinement factor} = 1.13916$

$y1 = 0.00130695$

$sh1 = 0.00451687$

$ft1 = 376.4017$

$fy1 = 313.6681$

$su1 = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{\min} = lb/ld = 0.30356779$

$su1 = 0.4 * esu1_{\text{nominal}}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_{\text{nominal}} = 0.08$,

For calculation of $esu1_{\text{nominal}}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 313.6681$

with $Es1 = Es = 200000.00$

$y2 = 0.00130695$

$$sh2 = 0.00451687$$

$$ft2 = 376.4017$$

$$fy2 = 313.6681$$

$$su2 = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/lb_{u,min} = 0.30356779$$

$$su2 = 0.4 * esu2_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and $y2$, $sh2, ft2, fy2$, it is considered
characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1$, $sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 313.6681$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00130695$$

$$shv = 0.00451687$$

$$ftv = 376.4017$$

$$fyv = 313.6681$$

$$suv = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/ld = 0.30356779$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_{nominal}$ and yv , shv, ftv, fyv , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1$, $sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 313.6681$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl_{ten}/(b*d) * (fs1/fc) = 0.1256764$$

$$2 = Asl_{com}/(b*d) * (fs2/fc) = 0.1256764$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.06093401$$

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = Asl_{ten}/(b*d) * (fs1/fc) = 0.16701987$$

$$2 = Asl_{com}/(b*d) * (fs2/fc) = 0.16701987$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.08097933$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vsy2$ - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.25329952$$

$$Mu = MRc (4.14) = 5.9930E+007$$

$$u = su (4.1) = 3.4011160E-005$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$

$$lb = 300.00$$

$$ld = 988.2471$$

Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$db = 18.00$$

Mean strength value of all re-bars: $fy = 555.55$

$$fc' = 20.00, \text{ but } fc'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

e = 1.00
cb = 25.00
Ktr = 4.61999
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 = 170.00
n = 8.00

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 265235.248$

Calculation of Shear Strength at edge 1, $V_{r1} = 265235.248$
 $V_{r1} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = knl * V_{CoI0}$
 $V_{CoI0} = 265235.248$
knl = 1 (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 2.3992784E-012$

$V_u = 2.9007121E-031$

$d = 0.8 * h = 200.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 49279.392$

$A_v = 157079.633$

$f_y = 444.44$

$s = 170.00$

V_s is multiplied by $\phi_{Col} = 0.60$

$s/d = 0.85$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 109072.851$

$f = 0.95$, 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: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$, with:

total thickness per orientation, $t_{f1} = NL * t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 207.00

$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$

$b_w = 500.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 265235.248$

$V_{r2} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = knl * V_{CoI0}$
 $V_{CoI0} = 265235.248$
knl = 1 (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 2.3992784E-012$

$V_u = 2.9007121E-031$

$d = 0.8 \cdot h = 200.00$
 $Nu = 4666.932$
 $Ag = 125000.00$
 From (11.5.4.8), ACI 318-14: $Vs = 49279.392$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 170.00$
 Vs is multiplied by $Col = 0.60$
 $s/d = 0.85$
 Vf ((11-3)-(11.4), ACI 440) = 109072.851
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / \text{NoDir} = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 207.00
 ffe ((11-5), ACI 440) = 259.312
 $Ef = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.01$
 From (11-11), ACI 440: $Vs + Vf \leq 297085.704$
 $bw = 500.00$

 End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At local axis: 3

 Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rcrs

Constant Properties

 Knowledge Factor, $\gamma = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Primary Member: Concrete Strength, $fc = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $fs = f_{sm} = 444.44$
 Concrete Elasticity, $Ec = 21019.039$
 Steel Elasticity, $Es = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $fs = 1.25 \cdot f_{sm} = 555.55$
 #####
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.13916
 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, $bi = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 1.3558547E-031$
EDGE -B-
Shear Force, $V_b = -1.3558547E-031$
BOTH EDGES
Axial Force, $F = -4666.932$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{l,ten} = 829.3805$
-Compression: $As_{l,com} = 829.3805$
-Middle: $As_{l,mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.23676754$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96937.922$
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 1.4541E+008$
 $\mu_{1+} = 1.4541E+008$, 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
 $\mu_{1-} = 1.4541E+008$, 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
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 1.4541E+008$
 $\mu_{2+} = 1.4541E+008$, 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
 $\mu_{2-} = 1.4541E+008$, 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:
 $\mu = 1.4467178E-005$
 $\mu_u = 1.4541E+008$

with full section properties:

$b = 250.00$
 $d = 457.00$
 $d' = 43.00$
 $v = 0.00204242$
 $N = 4666.932$
 $f_c = 20.00$
 $\alpha (5A.5, TBDY) = 0.002$
Final value of μ_c : $\mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \alpha) = 0.01464474$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\mu_c = 0.01464474$
 $\omega_e ((5.4c), TBDY) = \alpha * \text{sh}_{min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$
where $f = \alpha * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.07705054
af = 0.45253333
b = 500.00
h = 250.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.004064
bw = 500.00
effective stress from (A.35), ff,e = 837.9178

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128
bw = 250.00
effective stress from (A.35), ff,e = 703.4155

R = 40.00
Effective FRP thickness, tf = NL*t*cos(b1) = 1.016
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00

psh,min = Min(psh,x , psh,y) = 0.001848
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) = 0.001848
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^2/3), from 10.3.5, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695

shv = 0.00451687

ftv = 376.4017

fyv = 313.6681

suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127

2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127

v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062

and confined core properties:

b = 190.00

d = 427.00

d' = 13.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1603292

2 = Asl,com/(b*d)*(fs2/fc) = 0.1603292

v = Asl,mid/(b*d)*(fsv/fc) = 0.07773537

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.20486988

Mu = MRc (4.14) = 1.4541E+008

u = su (4.1) = 1.4467178E-005

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.30356779

lb = 300.00

ld = 988.2471

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 20.00, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 4.61999

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 = 170.00
n = 8.00

Calculation of Mu1-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:
 $\mu = 1.4467178E-005$
 $Mu = 1.4541E+008$

with full section properties:

b = 250.00
d = 457.00
d' = 43.00
v = 0.00204242
N = 4666.932

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu, \text{co}) = 0.01464474$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu = 0.01464474$

μ_e ((5.4c), TBDY) = $\text{ase} * \text{sh_min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07705054$

$af = 0.45253333$

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

bw = 500.00

effective stress from (A.35), $f_{fe} = 837.9178$

 $f_y = 0.12936483$

$af = 0.45253333$

b = 250.00

h = 500.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

bw = 250.00

effective stress from (A.35), $f_{fe} = 703.4155$

R = 40.00

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

ase ((5.4d), TBDY) = 0.03751166

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$\text{psh_min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.001848$

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) = 0.001848

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 500.00$

 psh_y (5.4d) = 0.00369599

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 250.00$

s = 170.00

$$fywe = 555.55$$

$$fce = 20.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00339158$

$$c = \text{confinement factor} = 1.13916$$

$$y1 = 0.00130695$$

$$sh1 = 0.00451687$$

$$ft1 = 376.4017$$

$$fy1 = 313.6681$$

$$su1 = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.30356779$$

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 313.6681$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00130695$$

$$sh2 = 0.00451687$$

$$ft2 = 376.4017$$

$$fy2 = 313.6681$$

$$su2 = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.30356779$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 313.6681$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00130695$$

$$shv = 0.00451687$$

$$ftv = 376.4017$$

$$fyv = 313.6681$$

$$suv = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.30356779$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 313.6681$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.1603292$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.1603292$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.07773537$$

Case/Assumption: Unconfinedsd full section - Steel rupture

satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

μ_u (4.9) = 0.20486988

μ_u = MRc (4.14) = 1.4541E+008

$u = \mu_u$ (4.1) = 1.4467178E-005

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$

where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis

$s = 170.00$

$n = 8.00$

Calculation of μ_{u2+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$u = 1.4467178E-005$

$\mu_u = 1.4541E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00204242$

$N = 4666.932$

$f_c = 20.00$

α_{co} (5A.5, TBDY) = 0.002

Final value of α_{cu} : $\alpha_{cu}^* = \text{shear_factor} * \text{Max}(\alpha_{cu}, \alpha_{cc}) = 0.01464474$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\alpha_{cu} = 0.01464474$

where α_{cu} ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(\alpha_{fx}, \alpha_{fy}) = 0.07762821$

where $\alpha_{fx} = \alpha_{se} * \text{pf} * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\alpha_{fx} = 0.07705054$

$\alpha_{se} = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f/b_w = 0.004064$

$b_w = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

 $\alpha_{fy} = 0.12936483$

$\alpha_{se} = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 703.4155$

R = 40.00

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se}((5.4d), TBDY) = 0.03751166$

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$

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)

$p_{sh,x} (5.4d) = 0.001848$

$A_{sh} = A_{stir} \cdot n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 500.00$

$p_{sh,y} (5.4d) = 0.00369599$

$A_{sh} = A_{stir} \cdot n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 250.00$

$s = 170.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.00339158$

$c = \text{confinement factor} = 1.13916$

$y_1 = 0.00130695$

$sh_1 = 0.00451687$

$ft_1 = 376.4017$

$fy_1 = 313.6681$

$su_1 = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30356779$

$su_1 = 0.4 \cdot \text{esu1_nominal}((5.5), TBDY) = 0.032$

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, ASCE41-17.

with $f_{s1} = f_s = 313.6681$

with $E_{s1} = E_s = 200000.00$

$y_2 = 0.00130695$

$sh_2 = 0.00451687$

$ft_2 = 376.4017$

$fy_2 = 313.6681$

$su_2 = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30356779$

$su_2 = 0.4 \cdot \text{esu2_nominal}((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $\text{esu2_nominal} = 0.08$,

For calculation of esu2_nominal and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s2} = f_s = 313.6681$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.00130695$

$sh_v = 0.00451687$

$ft_v = 376.4017$

$fy_v = 313.6681$

$su_v = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_0/l_{0u,min} = l_b/l_d = 0.30356779$$

$$s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv,nominal}$ and γ_v , sh_v, ft_v, fy_v , it is considered
characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.

γ_1 , sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{sv} = f_s = 313.6681$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.11385127$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.11385127$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.05520062$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 22.78316$$

$$c_c (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.1603292$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.1603292$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

$$s_u (4.9) = 0.20486988$$

$$M_u = M_{Rc} (4.14) = 1.4541E+008$$

$$u = s_u (4.1) = 1.4467178E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$$l_b = 300.00$$

$$l_d = 988.2471$$

Calculation of l_b,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

$$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$$

where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis

$$s = 170.00$$

$$n = 8.00$$

Calculation of M_u2

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.4467178E-005$$

$$M_u = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

d = 457.00

d' = 43.00

v = 0.00204242

N = 4666.932

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01464474$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01464474$

we ((5.4c), TBDY) = $ase * sh_{\min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.07762821$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.07705054

af = 0.45253333

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

bw = 500.00

effective stress from (A.35), $ff_e = 837.9178$

fy = 0.12936483

af = 0.45253333

b = 250.00

h = 500.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

bw = 250.00

effective stress from (A.35), $ff_e = 703.4155$

R = 40.00

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = 0.03751166

bo = 440.00

ho = 190.00

bi2 = 459400.00

psh,min = $\text{Min}(psh_x, psh_y) = 0.001848$

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) = 0.001848

Ash = $A_{stir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 500.00

psh,y (5.4d) = 0.00369599

Ash = $A_{stir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 250.00

s = 170.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$

c = confinement factor = 1.13916

y1 = 0.00130695

sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = $lb/d = 0.30356779$

su1 = $0.4 * esu1_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: $esu1_{\text{nominal}} = 0.08,$

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 313.6681$

with $Es1 = Es = 200000.00$

$y2 = 0.00130695$

$sh2 = 0.00451687$

$ft2 = 376.4017$

$fy2 = 313.6681$

$su2 = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lou, min = lb/lb, min = 0.30356779$

$su2 = 0.4 \cdot esu2_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 313.6681$

with $Es2 = Es = 200000.00$

$yv = 0.00130695$

$shv = 0.00451687$

$ftv = 376.4017$

$fyv = 313.6681$

$suv = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lou, min = lb/ld = 0.30356779$

$suv = 0.4 \cdot esuv_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fsv = fs = 313.6681$

with $Esv = Es = 200000.00$

1 = $Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.11385127$

2 = $Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.11385127$

v = $Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.05520062$

and confined core properties:

$b = 190.00$

$d = 427.00$

$d' = 13.00$

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = $Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.1603292$

2 = $Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.1603292$

v = $Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.07773537$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs, y2$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.20486988

$Mu = MRc$ (4.14) = 1.4541E+008

$u = su$ (4.1) = 1.4467178E-005

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$

$lb = 300.00$

$ld = 988.2471$

Calculation of lb, min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

s = 170.00

n = 8.00

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 409422.352$

Calculation of Shear Strength at edge 1, $V_{r1} = 409422.352$

$V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Col0}$

$V_{Col0} = 409422.352$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.8180236E-013$

$\nu_u = 1.3558547E-031$

d = $0.8 * h = 400.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 164264.64$

$A_v = 157079.633$

$f_y = 444.44$

s = 170.00

V_s is multiplied by $\text{Col} = 1.00$

s/d = 0.425

V_f ((11-3)-(11.4), ACI 440) = 240803.347

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 $(\cot \theta + \text{cota}) \sin \alpha$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 457.00

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: $V_s + V_f \leq 297085.704$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 409422.352$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Col0}$

$V_{Col0} = 409422.352$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 2.8180236E-013$
 $\nu_u = 1.3558547E-031$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 164264.64$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.425$
 V_f ((11-3)-(11.4), ACI 440) = 240803.347
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $t_{f1} = NL \cdot t / N_{\text{Dir}} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 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: $V_s + V_f \leq 297085.704$
 $b_w = 250.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
 At local axis: 2
 Integration Section: (a)
 Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 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, $M = 9.9150700E-010$

Shear Force, $V_2 = -4708.27$

Shear Force, $V_3 = -3.5022564E-013$

Axial Force, $F = -4886.081$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 1231.504$

-Compression: $A_{sl,c} = 829.3805$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 829.3805$

-Compression: $A_{sl,com} = 829.3805$

-Middle: $A_{sl,mid} = 402.1239$

Mean Diameter of Tension Reinforcement, $D_bL = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.04410058$

$u = y + p = 0.04410058$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00620957$ ((4.29), Biskinis Phd)

$M_y = 5.0984E+007$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1053E+012$

factor = 0.30

$A_g = 125000.00$

$f_c' = 20.00$

$N = 4886.081$

$E_c * I_g = 1.3684E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 1.0451750E-005$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 291.1836$

$d = 207.00$

$y = 0.32705805$

$A = 0.02007406$

$B = 0.01218624$

with $pt = 0.00801334$

$pc = 0.00801334$

$p_v = 0.00388525$

$N = 4886.081$

$b = 500.00$

" = 0.20772947

$y_{comp} = 2.5957131E-005$

with $f_c * (12.3, (ACI 440)) = 20.44529$

$f_c = 20.00$

$f_l = 0.9425867$
 $b = 500.00$
 $h = 250.00$
 $A_g = 125000.00$
 From (12.9), ACI 440: $k_a = 0.1506892$
 $g = p_t + p_c + p_v = 0.01991193$
 $rc = 40.00$
 $A_e/A_c = 0.60275679$
 Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.32585609$
 $A = 0.01977712$
 $B = 0.01202411$
 with $E_s = 200000.00$

 Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.37945973$

$l_b = 300.00$

$l_d = 790.5977$

Calculation of I according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 170.00$

$n = 8.00$

 - Calculation of ρ -

From table 10-8: $\rho = 0.03789101$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$

shear control ratio $V_y E / V_{CoI} E = 0.15063296$

$d = 207.00$

$s = 0.00$

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$

$A_v = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$b_w = 500.00$

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.

$NUD = 4886.081$

$A_g = 125000.00$

$f_c E = 20.00$

$f_{yE} = f_{yI} E = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.01991193$

$b = 500.00$

$d = 207.00$

$f_c E = 20.00$

 End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 11

column C1, Floor 1

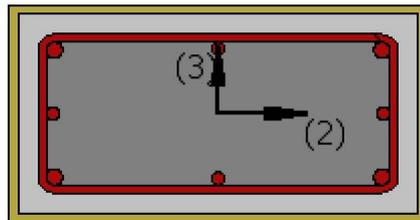
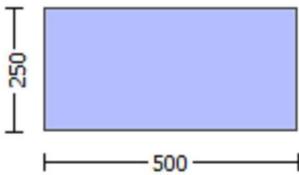
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

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, $M_a = 9.9150700E-010$
Shear Force, $V_a = -3.5022564E-013$
EDGE -B-
Bending Moment, $M_b = 6.0169508E-011$
Shear Force, $V_b = 3.5022564E-013$
BOTH EDGES
Axial Force, F = -4886.081
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 1231.504$
-Compression: $A_{sl,c} = 829.3805$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 829.3805$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 402.1239$
Mean Diameter of Tension Reinforcement, $D_{bL,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 248589.15$
 V_n ((10.3), ASCE 41-17) = $k_n l V_{CoI0} = 248589.15$
 $V_{CoI} = 248589.15$
 $k_n l = 1.00$
displacement_ductility_demand = 0.00

NOTE: In expression (10-3) ' $V_s = A_v f_y d/s$ ' is replaced by ' $V_s + \phi V_f$ '
where V_f is the contribution of FRPs ((11.3), ACI 440).

= 1 (normal-weight concrete)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 9.9150700E-010$
 $V_u = 3.5022564E-013$
 $d = 0.8 \cdot h = 200.00$
 $N_u = 4886.081$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 44351.896$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 170.00$
 V_s is multiplied by $CoI = 0.60$
 $s/d = 0.85$
 V_f ((11-3)-(11.4), ACI 440) = 109072.851
 $\phi = 0.95$, for fully-wrapped sections

$wf/sf = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \theta$ 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) = 207.00

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: $V_s + V_f \leq 265721.532$

$b_w = 500.00$

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 $\theta = 6.6390666E-020$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00620957$ ((4.29), Biskinis Phd)

$M_y = 5.0984E+007$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 4.1053E+012$

factor = 0.30

$A_g = 125000.00$

$f_c' = 20.00$

$N = 4886.081$

$E_c \cdot I_g = 1.3684E+013$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 1.0451750E-005$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 291.1836$

$d = 207.00$

$y = 0.32705805$

$A = 0.02007406$

$B = 0.01218624$

with $p_t = 0.00801334$

$p_c = 0.00801334$

$p_v = 0.00388525$

$N = 4886.081$

$b = 500.00$

$\alpha = 0.20772947$

$y_{comp} = 2.5957131E-005$

with f_c' (12.3, (ACI 440)) = 20.44529

$f_c = 20.00$

$f_l = 0.9425867$

$b = 500.00$

$h = 250.00$

$A_g = 125000.00$

From (12.9), ACI 440: $k_a = 0.1506892$

$g = p_t + p_c + p_v = 0.01991193$

$r_c = 40.00$

$A_e / A_c = 0.60275679$

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

effective strain from (12.5) and (12.12), $e_{fe} = 0.004$

$f_u = 0.01$

Ef = 64828.00
Ec = 21019.039
y = 0.32585609
A = 0.01977712
B = 0.01202411
with Es = 200000.00

Calculation of ratio lb/l_d

Lap Length: l_d/l_{d,min} = 0.37945973

l_b = 300.00

l_d = 790.5977

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: f_y = 444.44

f_c' = 20.00, but f_c'^{0.5} ≤ 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

K_{tr} = 4.61999

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 = 170.00

n = 8.00

End Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 12

column C1, Floor 1

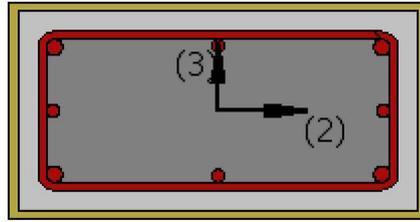
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (u)

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At Shear local axis: 3
(Bending local axis: 2)
Section Type: rcrs

Constant Properties

Knowledge Factor, = 1.00

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

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, $V_a = 2.9007121E-031$

EDGE -B-

Shear Force, $V_b = -2.9007121E-031$

BOTH EDGES

Axial Force, $F = -4666.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 829.3805$

-Compression: $As_{c,com} = 829.3805$

-Middle: $As_{mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.15063296$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 39953.171$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 5.9930E+007$

$Mu_{1+} = 5.9930E+007$, 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

$Mu_{1-} = 5.9930E+007$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 5.9930E+007$

$Mu_{2+} = 5.9930E+007$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 5.9930E+007$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 3.4011160E-005$

$M_u = 5.9930E+007$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00225456$

$N = 4666.932$

$f_c = 20.00$

ϕ_c (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01464474$

ϕ_{ve} ((5.4c), TBDY) = $\phi_u * \text{sh}_{\min} * f_{yve}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$

where $\phi = \phi_f * \phi_{ff,e}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.07705054$

$\phi_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\phi_f = 2t_f/b_w = 0.004064$

$b_w = 500.00$

effective stress from (A.35), $\phi_{ff,e} = 837.9178$

$\phi_y = 0.12936483$

$\phi_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $\phi_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $\phi_{ff,e} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \text{Cos}(\beta_1) = 1.016$

$f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase \text{ ((5.4d), TBDY)} = 0.03751166$
 $bo = 440.00$
 $ho = 190.00$
 $bi2 = 459400.00$

$psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.001848$
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)

 $psh_{,x} \text{ (5.4d)} = 0.001848$
 $A_{sh} = A_{stir} * n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $bk = 500.00$

 $psh_{,y} \text{ (5.4d)} = 0.00369599$
 $A_{sh} = A_{stir} * n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $bk = 250.00$

 $s = 170.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$

$y_1 = 0.00130695$
 $sh_1 = 0.00451687$
 $ft_1 = 376.4017$
 $fy_1 = 313.6681$
 $su_1 = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lo_{,min} = lb/ld = 0.30356779$

$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 313.6681$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00130695$
 $sh_2 = 0.00451687$
 $ft_2 = 376.4017$
 $fy_2 = 313.6681$
 $su_2 = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lo_{,min} = lb/lb_{,min} = 0.30356779$

$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 313.6681$

with $Es_2 = Es = 200000.00$

$y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $suv = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lo_{,min} = lb/ld = 0.30356779$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_nominal$ and yv , shv,ftv,fyv , it is considered characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1$, $sh1,ft1,fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fsv = fs = 313.6681$

with $Esv = Es = 200000.00$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401$$

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

c = confinement factor = 1.13916

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < vs,y2$ - LHS eq.(4.5) is satisfied

$$su (4.9) = 0.25329952$$

$$Mu = MRc (4.14) = 5.9930E+007$$

$$u = su (4.1) = 3.4011160E-005$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$

$$lb = 300.00$$

$$ld = 988.2471$$

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$db = 18.00$$

Mean strength value of all re-bars: $fy = 555.55$

$fc' = 20.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$Ktr = 4.61999$$

$$Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$$

where Atr_x , Atr_y are the sum of the area of all stirrup legs along X and Y local axis

$$s = 170.00$$

$$n = 8.00$$

Calculation of $Mu1$ -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 3.4011160E-005$$

$$Mu = 5.9930E+007$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00225456$$

$$N = 4666.932$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464474$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01464474$$

$$\text{we ((5.4c), TBDY)} = a_s e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s e \text{ ((5.4d), TBDY)} = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.001848$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00369599$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A.5), TBDY), TBDY: } c_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00130695$$

$$sh_1 = 0.00451687$$

$$ft_1 = 376.4017$$

$$fy_1 = 313.6681$$

$$su_1 = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o / l_{o,\min} = l_b / l_d = 0.30356779$$

$$su_1 = 0.4 * esu_1_{\text{nominal}} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu_1_{\text{nominal}} = 0.08$,

For calculation of esu_1_{nominal} and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1 / 1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 313.6681$$

with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.00130695$
 $sh_2 = 0.00451687$
 $ft_2 = 376.4017$
 $fy_2 = 313.6681$
 $su_2 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.30356779$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $fs_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 313.6681$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.30356779$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fs_v = fs_v/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fs_v = fs_v/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_v = fs = 313.6681$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{s1,ten}/(b*d) * (fs_1/f_c) = 0.1256764$
 $2 = A_{s1,com}/(b*d) * (fs_2/f_c) = 0.1256764$
 $v = A_{s1,mid}/(b*d) * (fs_v/f_c) = 0.06093401$
 and confined core properties:
 $b = 440.00$
 $d = 177.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{s1,ten}/(b*d) * (fs_1/f_c) = 0.16701987$
 $2 = A_{s1,com}/(b*d) * (fs_2/f_c) = 0.16701987$
 $v = A_{s1,mid}/(b*d) * (fs_v/f_c) = 0.08097933$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_s, y_2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.25329952$
 $M_u = MR_c (4.14) = 5.9930E+007$
 $u = su (4.1) = 3.4011160E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$
 $l_b = 300.00$
 $l_d = 988.2471$
 Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 20.00$, but $fc^{0.5} <= 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 4.61999
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 = 170.00
n = 8.00

Calculation of Mu2+

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

u = 3.4011160E-005
Mu = 5.9930E+007

with full section properties:

b = 500.00
d = 207.00
d' = 43.00
v = 0.00225456
N = 4666.932
fc = 20.00
co (5A.5, TBDY) = 0.002
Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_u = 0.01464474$
 ϕ_{we} ((5.4c), TBDY) = $\text{ase} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$
where $\phi = \text{af} * \text{pf} * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\phi_x = 0.07705054$
 $\text{af} = 0.45253333$
b = 500.00
h = 250.00
From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.004064$
 $b_w = 500.00$
effective stress from (A.35), $f_{fe} = 837.9178$

 $\phi_y = 0.12936483$
 $\text{af} = 0.45253333$
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.008128$
 $b_w = 250.00$
effective stress from (A.35), $f_{fe} = 703.4155$

R = 40.00
Effective FRP thickness, $t_f = \text{NL} * t * \text{Cos}(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{f} = 0.015$
 ase ((5.4d), TBDY) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00
 $\text{psh}_{\min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.001848$
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) = 0.001848
Ash = Astir * ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764

2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764

v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401

and confined core properties:

b = 440.00
d = 177.00
d' = 13.00

f_{cc} (5A.2, TBDY) = 22.78316
 c_c (5A.5, TBDY) = 0.00339158
 c = confinement factor = 1.13916
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16701987$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.16701987$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08097933$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->
 μ_u (4.9) = 0.25329952
 $M_u = M_{Rc}$ (4.14) = 5.9930E+007
 $u = \mu_u$ (4.1) = 3.4011160E-005

 Calculation of ratio l_b/l_d

 Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$
 $l_d = 988.2471$

Calculation of l_b, min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 = 1

$d_b = 18.00$
 Mean strength value of all re-bars: $f_y = 555.55$
 $f_c' = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $c_b = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$
 where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

 Calculation of μ_u

 Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$u = 3.4011160E-005$
 $M_u = 5.9930E+007$

 with full section properties:

$b = 500.00$
 $d = 207.00$
 $d' = 43.00$
 $v = 0.00225456$
 $N = 4666.932$
 $f_c = 20.00$
 c_o (5A.5, TBDY) = 0.002
 Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464474$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $c_u = 0.01464474$
 w_e ((5.4c), TBDY) = $a_s * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$
 where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07705054$
 $a_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$
 From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.004064$
 $b_w = 500.00$
 effective stress from (A.35), $f_{f,e} = 837.9178$

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128
bw = 250.00
effective stress from (A.35), ff,e = 703.4155

R = 40.00
Effective FRP thickness, tf = NL*t*Cos(b1) = 1.016
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.001848

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) = 0.001848
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^2/3), from 10.3.5, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^2/3), from 10.3.5, ASCE41-17.

with $f_{s2} = f_s = 313.6681$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $su_v = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30356779$
 $su_v = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $f_{sv} = f_s = 313.6681$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.1256764$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.1256764$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.06093401$

and confined core properties:

$b = 440.00$
 $d = 177.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.16701987$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.16701987$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.08097933$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

$su (4.9) = 0.25329952$

$Mu = MRc (4.14) = 5.9930E+007$

$u = su (4.1) = 3.4011160E-005$

 Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

Calculation of l_b,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = Min(A_{tr,x}, A_{tr,y}) = 157.0796$

where $A_{tr,x}, A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis

$s = 170.00$

$n = 8.00$

 Calculation of Shear Strength $V_r = Min(V_{r1}, V_{r2}) = 265235.248$

Calculation of Shear Strength at edge 1, $Vr1 = 265235.248$

$Vr1 = VCol$ ((10.3), ASCE 41-17) = $knl * VColO$

$VColO = 265235.248$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $Vs = Av * fy * d / s$ ' is replaced by ' $Vs + f * Vf$ ' where Vf is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)

$fc' = 20.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu = 2.3992784E-012$

$Vu = 2.9007121E-031$

$d = 0.8 * h = 200.00$

$Nu = 4666.932$

$Ag = 125000.00$

From (11.5.4.8), ACI 318-14: $Vs = 49279.392$

$Av = 157079.633$

$fy = 444.44$

$s = 170.00$

Vs is multiplied by $\lambda = 0.60$

$s/d = 0.85$

Vf ((11-3)-(11.4), ACI 440) = 109072.851

$f = 0.95$, for fully-wrapped sections

$wf/sf = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $Vf(\theta, \alpha)$, 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: $\theta = 45^\circ + 90^\circ = 135^\circ$

$Vf = \text{Min}(|Vf(45, 1)|, |Vf(-45, 1)|)$, with:

total thickness per orientation, $tf1 = NL * t / NoDir = 1.016$

$dfv = d$ (figure 11.2, ACI 440) = 207.00

ffe ((11-5), ACI 440) = 259.312

$Ef = 64828.00$

$fe = 0.004$, from (11.6a), ACI 440

with $fu = 0.01$

From (11-11), ACI 440: $Vs + Vf \leq 297085.704$

$bw = 500.00$

Calculation of Shear Strength at edge 2, $Vr2 = 265235.248$

$Vr2 = VCol$ ((10.3), ASCE 41-17) = $knl * VColO$

$VColO = 265235.248$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $Vs = Av * fy * d / s$ ' is replaced by ' $Vs + f * Vf$ ' where Vf is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)

$fc' = 20.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu = 2.3992784E-012$

$Vu = 2.9007121E-031$

$d = 0.8 * h = 200.00$

$Nu = 4666.932$

$Ag = 125000.00$

From (11.5.4.8), ACI 318-14: $Vs = 49279.392$

$Av = 157079.633$

$fy = 444.44$

$s = 170.00$

Vs is multiplied by $\lambda = 0.60$

$s/d = 0.85$

Vf ((11-3)-(11.4), ACI 440) = 109072.851

$f = 0.95$, 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 $V_f(\theta)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $b_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:

total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 207.00

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: $V_s + V_f \leq 297085.704$

$b_w = 500.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

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, $\text{NoDir} = 1$

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, $V_a = 1.3558547E-031$

EDGE -B-

Shear Force, $V_b = -1.3558547E-031$

BOTH EDGES

Axial Force, $F = -4666.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{st,ten} = 829.3805$

-Compression: $A_{sl,com} = 829.3805$

-Middle: $A_{sl,mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.23676754$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96937.922$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.4541E+008$

$M_{u1+} = 1.4541E+008$, 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

$M_{u1-} = 1.4541E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.4541E+008$

$M_{u2+} = 1.4541E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 1.4541E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of M_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.4467178E-005$

$M_u = 1.4541E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00204242$

$N = 4666.932$

$f_c = 20.00$

$\alpha_{co} (5A.5, TBDY) = 0.002$

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01464474$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_{cu} = 0.01464474$

$\phi_{we} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07762821$

where $\phi_f = \alpha_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_{fx} = 0.07705054$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$\phi_{fy} = 0.12936483$

$\alpha_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$
 $bw = 250.00$
effective stress from (A.35), $ff,e = 703.4155$

R = 40.00
Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase \text{ ((5.4d), TBDY)} = 0.03751166$
 $bo = 440.00$
 $ho = 190.00$
 $bi2 = 459400.00$
 $psh_{,min} = \text{Min}(psh,x, psh,y) = 0.001848$

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)

$psh,x \text{ (5.4d)} = 0.001848$
 $A_{sh} = A_{stir}*ns = 78.53982$
No stirrups, $ns = 2.00$
 $bk = 500.00$

$psh,y \text{ (5.4d)} = 0.00369599$
 $A_{sh} = A_{stir}*ns = 78.53982$
No stirrups, $ns = 2.00$
 $bk = 250.00$

$s = 170.00$
 $fy_{we} = 555.55$
 $f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$

$y1 = 0.00130695$
 $sh1 = 0.00451687$
 $ft1 = 376.4017$
 $fy1 = 313.6681$
 $su1 = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou_{,min} = lb/ld = 0.30356779$

$su1 = 0.4*esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 313.6681$
with $Es1 = Es = 200000.00$

$y2 = 0.00130695$
 $sh2 = 0.00451687$
 $ft2 = 376.4017$
 $fy2 = 313.6681$
 $su2 = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou_{,min} = lb/lb_{,min} = 0.30356779$

$su2 = 0.4*esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and $y2, sh2, ft2, fy2$, it is considered
characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 313.6681$
with $Es2 = Es = 200000.00$

$yv = 0.00130695$
 $shv = 0.00451687$
 $ftv = 376.4017$

$$f_{yv} = 313.6681$$

$$s_{uv} = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.30356779$$

$$s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$$

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, ASCE41-17.

$$\text{with } f_{sv} = f_s = 313.6681$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.11385127$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11385127$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.05520062$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 22.78316$$

$$c_c (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1603292$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1603292$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.20486988$$

$$M_u = M_{Rc} (4.14) = 1.4541E+008$$

$$u = s_u (4.1) = 1.4467178E-005$$

Calculation of ratio l_b/l_d

$$\text{Lap Length: } l_b/l_d = 0.30356779$$

$$l_b = 300.00$$

$$l_d = 988.2471$$

Calculation of l_b ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

$$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$$

where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis

$$s = 170.00$$

$$n = 8.00$$

Calculation of M_{u1} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.4467178E-005$$

$$M_u = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

$$\alpha (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \alpha: \alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01464474$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \alpha = 0.01464474$$

$$\omega_e ((5.4c), \text{TBDY}) = \alpha^* \cdot \text{sh}_{\min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

where $f = \alpha^* \cdot \rho_f \cdot f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07705054$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$f_y = 0.12936483$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} ((5.4d), \text{TBDY}) = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$\rho_{sh,\min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.001848$$

Expression ((5.4d), TBDY) for $\rho_{sh,\min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\rho_{sh,x} (5.4d) = 0.001848$$

$$A_{sh} = A_{stir} \cdot n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$\rho_{sh,y} (5.4d) = 0.00369599$$

$$A_{sh} = A_{stir} \cdot n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \alpha_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00130695$$

$$\text{sh}_1 = 0.00451687$$

$$f_{t1} = 376.4017$$

$$f_{y1} = 313.6681$$

$$s_{u1} = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,\min} = l_b/d = 0.30356779$$

$$su_1 = 0.4 * esu_{1_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{1_nominal} = 0.08$,

For calculation of $esu_{1_nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 313.6681$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00130695$$

$$sh_2 = 0.00451687$$

$$ft_2 = 376.4017$$

$$fy_2 = 313.6681$$

$$su_2 = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou, \text{min} = lb/lb, \text{min} = 0.30356779$$

$$su_2 = 0.4 * esu_{2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{2_nominal} = 0.08$,

For calculation of $esu_{2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 313.6681$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00130695$$

$$sh_v = 0.00451687$$

$$ft_v = 376.4017$$

$$fy_v = 313.6681$$

$$su_v = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.30356779$$

$$su_v = 0.4 * esu_{v_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{v_nominal} = 0.08$,

considering characteristic value $fsy_v = fsv/1.2$, from table 5.1, TBDY

For calculation of $esu_{v_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered characteristic value $fsy_v = fsv/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 313.6681$$

$$\text{with } Es_v = Es = 200000.00$$

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.11385127$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.11385127$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.05520062$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.1603292$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.1603292$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

$$su (4.9) = 0.20486988$$

$$Mu = MRc (4.14) = 1.4541E+008$$

$$u = su (4.1) = 1.4467178E-005$$

Calculation of ratio lb/ld

$$\text{Lap Length: } lb/ld = 0.30356779$$

$$lb = 300.00$$

ld = 988.2471

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 20.00, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 4.61999

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 = 170.00

n = 8.00

Calculation of Mu2+

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

u = 1.4467178E-005

Mu = 1.4541E+008

with full section properties:

b = 250.00

d = 457.00

d' = 43.00

v = 0.00204242

N = 4666.932

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01464474$

we ((5.4c), TBDY) = $\text{ase} * \text{sh}_{\text{min}} * \text{fy}_{\text{we}} / \text{fce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$

where $\phi = \text{af} * \text{pf} * \text{ffe} / \text{fce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.07705054$

af = 0.45253333

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), pf = $2t_f / b_w = 0.004064$

b_w = 500.00

effective stress from (A.35), ffe = 837.9178

$\phi_y = 0.12936483$

af = 0.45253333

b = 250.00

h = 500.00

From EC8 A.4.4.3(6), pf = $2t_f / b_w = 0.008128$

b_w = 250.00

effective stress from (A.35), ffe = 703.4155

R = 40.00

Effective FRP thickness, tf = $NL * t * \text{Cos}(b_1) = 1.016$

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = 0.03751166

bo = 440.00

ho = 190.00

bi2 = 459400.00

psh,min = Min(psh,x, psh,y) = 0.001848

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) = 0.001848
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11385127$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.05520062$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 22.78316$$

$$c_c (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1603292$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1603292$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.20486988$$

$$M_u = M_{Rc} (4.14) = 1.4541E+008$$

$$u = s_u (4.1) = 1.4467178E-005$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.30356779$

$$l_b = 300.00$$

$$l_d = 988.2471$$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 170.00$$

$$n = 8.00$$

Calculation of M_u2 -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.4467178E-005$$

$$M_u = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464474$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01464474$$

$$\text{we ((5.4c), TBDY) } = a_s * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07705054$$

af = 0.45253333
b = 500.00
h = 250.00
From EC8 A.4.4.3(6), pf = $2t_f/bw = 0.004064$
bw = 500.00
effective stress from (A.35), ff,e = 837.9178

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), pf = $2t_f/bw = 0.008128$
bw = 250.00
effective stress from (A.35), ff,e = 703.4155

R = 40.00
Effective FRP thickness, tf = $NL*t*Cos(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = $Min(psh,x, psh,y) = 0.001848$
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) = 0.001848
Ash = $Astir*ns = 78.53982$
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = $Astir*ns = 78.53982$
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = $lb/ld = 0.30356779$
su1 = $0.4*esu1_nominal ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = $fs1/1.2$, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by $Min(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
with fs1 = fs = 313.6681
with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_{b,min} = 0.30356779$$

$$s_u2 = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su2,nominal} = 0.08$,

For calculation of $e_{su2,nominal}$ and y_2 , sh_2, ft_2, fy_2 , it is considered characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_1 , sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s2} = f_s = 313.6681$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.00130695$$

$$sh_v = 0.00451687$$

$$ft_v = 376.4017$$

$$fy_v = 313.6681$$

$$s_{uv} = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_d = 0.30356779$$

$$s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv,nominal}$ and y_v , sh_v, ft_v, fy_v , it is considered characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1 , sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{sv} = f_s = 313.6681$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.11385127$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.11385127$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.05520062$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 22.78316$$

$$c_c (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.1603292$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.1603292$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.20486988$$

$$\mu_u = M_{Rc} (4.14) = 1.4541E+008$$

$$u = s_u (4.1) = 1.4467178E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$$l_b = 300.00$$

$$l_d = 988.2471$$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f'_c = 20.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 170.00$$

$$n = 8.00$$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 409422.352$

Calculation of Shear Strength at edge 1, $V_{r1} = 409422.352$

$V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Col0}$

$V_{Col0} = 409422.352$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

 $= 1$ (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / V d = 2.00$

$\mu_u = 2.8180236E-013$

$V_u = 1.3558547E-031$

$d = 0.8 * h = 400.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 164264.64$

$A_v = 157079.633$

$f_y = 444.44$

$s = 170.00$

V_s is multiplied by $Col = 1.00$

$s / d = 0.425$

V_f ((11-3)-(11.4), ACI 440) = 240803.347

$f = 0.95$, 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 $V_f(\alpha, a_i)$, 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: $\alpha_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 457.00

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: $V_s + V_f \leq 297085.704$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 409422.352$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Col0}$

$V_{Col0} = 409422.352$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

 $= 1$ (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / V d = 2.00$

$\mu_u = 2.8180236E-013$

$V_u = 1.3558547E-031$

$d = 0.8 * h = 400.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 164264.64$

$A_v = 157079.633$

$f_y = 444.44$

$s = 170.00$

Vs is multiplied by Col = 1.00

s/d = 0.425

Vf ((11-3)-(11.4), ACI 440) = 240803.347

f = 0.95, for fully-wrapped sections

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(θ , α), is implemented for every different fiber orientation ai, as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$

Vf = Min(|Vf(45, θ_1)|, |Vf(-45, θ_1)|), with:

total thickness per orientation, tf1 = NL*t/NoDir = 1.016

dfv = d (figure 11.2, ACI 440) = 457.00

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 <= 297085.704

bw = 250.00

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Section Height, H = 250.00

Section Width, W = 500.00

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, NoDir = 1

Fiber orientations, $\theta_i = 0.00^\circ$

Number of layers, NL = 1

Radius of rounding corners, R = 40.00

Stepwise Properties

Bending Moment, $M = -1.4246E+007$
Shear Force, $V2 = -4708.27$
Shear Force, $V3 = -3.5022564E-013$
Axial Force, $F = -4886.081$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 1231.504$
-Compression: $As_c = 829.3805$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{,ten} = 829.3805$
-Compression: $As_{,com} = 829.3805$
-Middle: $As_{,mid} = 402.1239$
Mean Diameter of Tension Reinforcement, $Db_L = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = u = 0.04902323$
 $u = y + p = 0.04902323$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00702323$ ((4.29), Biskinis Phd)
 $M_y = 1.1435E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3025.674
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.6421E+013$
factor = 0.30
 $A_g = 125000.00$
 $f_c' = 20.00$
 $N = 4886.081$
 $E_c * I_g = 5.4737E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{,ten}, y_{,com})$
 $y_{,ten} = 4.5289398E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 291.1836$
 $d = 457.00$
 $y = 0.29656463$
 $A = 0.01818525$
 $B = 0.01001469$
with $pt = 0.00725935$
 $pc = 0.00725935$
 $p_v = 0.00351968$
 $N = 4886.081$
 $b = 250.00$
 $" = 0.0940919$
 $y_{,comp} = 1.2978922E-005$
with f_c^* (12.3, (ACI 440)) = 20.44585
 $f_c = 20.00$
 $f_l = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $A_g = 125000.00$
From (12.9), ACI 440: $k_a = 0.15087868$
 $g = pt + pc + p_v = 0.01803838$
 $rc = 40.00$
 $A_e / A_c = 0.60351471$
Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$

y = 0.29519565
A = 0.01791625
B = 0.00986782
with Es = 200000.00

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.37945973$

$l_b = 300.00$

$l_d = 790.5977$

Calculation of I according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

s = 170.00

n = 8.00

- Calculation of ρ -

From table 10-8: $\rho = 0.042$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
shear control ratio $V_y E / V_{col} O E = 0.23676754$

$d = 457.00$

s = 0.00

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$

$A_v = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$b_w = 250.00$

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 = 4886.081

$A_g = 125000.00$

$f_c E = 20.00$

$f_{tE} = f_{yE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.01803838$

b = 250.00

d = 457.00

$f_c E = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 13

column C1, Floor 1

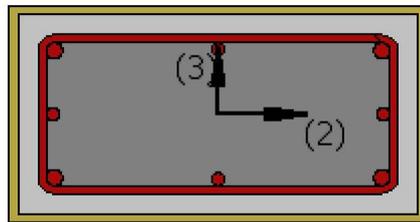
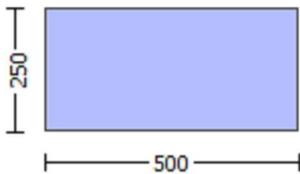
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

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, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -1.4246E+007$

Shear Force, $V_a = -4708.27$

EDGE -B-

Bending Moment, $M_b = 117197.472$

Shear Force, $V_b = 4708.27$

BOTH EDGES

Axial Force, $F = -4886.081$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 829.3805$

-Compression: $A_{sl,com} = 829.3805$

-Middle: $A_{sl,mid} = 402.1239$

Mean Diameter of Tension Reinforcement, $D_{bL,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 366339.577$

V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoI} = 366339.577$

$V_{CoI} = 366339.577$

$k_n = 1.00$

$displacement_ductility_demand = 0.18962367$

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + \phi V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$M_u = 117197.472$

$V_u = 4708.27$

$d = 0.8 \cdot h = 400.00$

$N_u = 4886.081$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 147839.654$

$A_v = 157079.633$

$f_y = 400.00$

$s = 170.00$

V_s is multiplied by $\phi_{CoI} = 1.00$

$s/d = 0.425$

V_f ((11-3)-(11.4), ACI 440) = 240803.347

$\phi = 0.95$, 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: $\theta = 45^\circ + 90^\circ = 135^\circ$

$V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|)$, with:

total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 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: $V_s + V_f \leq 265721.532$
 $b_w = 250.00$

displacement ductility demand is calculated as δ / y

- Calculation of δ / y for END B -
for rotation axis 3 and integ. section (b)

From analysis, chord rotation = 0.00013205
 $y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00069636$ ((4.29), Biskinis Phd)
 $M_y = 1.1435E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00
From table 10.5, ASCE 41_17: $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 1.6421E+013$
factor = 0.30
 $A_g = 125000.00$
 $f_c' = 20.00$
 $N = 4886.081$
 $E_c \cdot I_g = 5.4737E+013$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 4.5289398E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 291.1836$
 $d = 457.00$
 $y = 0.29656463$
 $A = 0.01818525$
 $B = 0.01001469$
with $p_t = 0.00725935$
 $p_c = 0.00725935$
 $p_v = 0.00351968$
 $N = 4886.081$
 $b = 250.00$
 $\lambda = 0.0940919$
 $y_{\text{comp}} = 1.2978922E-005$
with $f_c' = 20.00$ (12.3, (ACI 440)) = 20.44585
 $f_l = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $A_g = 125000.00$
From (12.9), ACI 440: $k_a = 0.15087868$
 $g = p_t + p_c + p_v = 0.01803838$
 $r_c = 40.00$
 $A_e / A_c = 0.60351471$
Effective FRP thickness, $t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.29519565$
 $A = 0.01791625$
 $B = 0.00986782$
with $E_s = 200000.00$

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.37945973$

$l_b = 300.00$

$l_d = 790.5977$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 170.00$

$n = 8.00$

End Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 14

column C1, Floor 1

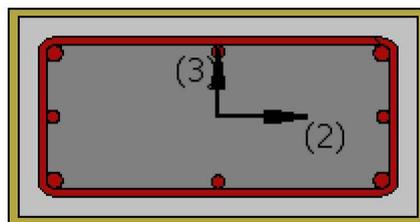
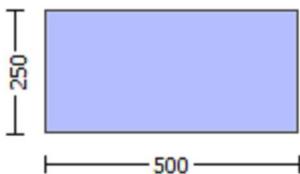
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ)

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)
Section Type: rcrs

Constant Properties

Knowledge Factor, $k = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

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: 3

EDGE -A-

Shear Force, $V_a = 2.9007121E-031$

EDGE -B-

Shear Force, $V_b = -2.9007121E-031$

BOTH EDGES

Axial Force, $F = -4666.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 829.3805$

-Compression: $A_{sl,com} = 829.3805$

-Middle: $A_{sl,mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.15063296$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 39953.171$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 5.9930E+007$

$M_{u1+} = 5.9930E+007$, 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

$Mu_{1-} = 5.9930E+007$, 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

$Mpr_2 = \text{Max}(Mu_{2+}, Mu_{2-}) = 5.9930E+007$

$Mu_{2+} = 5.9930E+007$, 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

$Mu_{2-} = 5.9930E+007$, 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:

$\phi_u = 3.4011160E-005$

$Mu = 5.9930E+007$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00225456$

$N = 4666.932$

$f_c = 20.00$

$\alpha_{co} (5A.5, TBDY) = 0.002$

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01464474$

$\phi_{we} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$

where $\phi_x = \alpha_f * \phi_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\phi_x = 0.07705054$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\phi_f = 2t_f / b_w = 0.004064$

$b_w = 500.00$

effective stress from (A.35), $f_{f,e} = 837.9178$

$\phi_y = 0.12936483$

$\alpha_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $\phi_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\alpha_{se} ((5.4d), TBDY) = 0.03751166$

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$

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)

 $p_{sh,x} (5.4d) = 0.001848$

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 500.00$

$p_{sh,y} (5.4d) = 0.00369599$

Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764

2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764

v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401

and confined core properties:

b = 440.00
d = 177.00
d' = 13.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916
1 = $A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16701987$
2 = $A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.16701987$
v = $A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08097933$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->
v < $v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->
su (4.9) = 0.25329952
Mu = MRc (4.14) = 5.9930E+007
u = su (4.1) = 3.4011160E-005

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.30356779

lb = 300.00

l_d = 988.2471

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 20.00, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

K_{tr} = 4.61999

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 = 170.00

n = 8.00

Calculation of Mu1-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 3.4011160E-005

Mu = 5.9930E+007

with full section properties:

b = 500.00

d = 207.00

d' = 43.00

v = 0.00225456

N = 4666.932

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01464474

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01464474

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+ Min(fx, fy) = 0.07762821

where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.07705054

af = 0.45253333

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.004064

bw = 500.00

effective stress from (A.35), ff,e = 837.9178

fy = 0.12936483

af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), pf = $2t_f/bw = 0.008128$
bw = 250.00
effective stress from (A.35), ff,e = 703.4155

R = 40.00
Effective FRP thickness, tf = $NL*t*\text{Cos}(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = $\text{Min}(psh,x, psh,y) = 0.001848$

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) = 0.001848
Ash = $\text{Astir}*ns = 78.53982$
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = $\text{Astir}*ns = 78.53982$
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su1 = $0.4*esu1_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su2 = $0.4*esu2_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764

2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764

v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401

and confined core properties:

b = 440.00

d = 177.00

d' = 13.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987

2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987

v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

v < vs,y2 - LHS eq.(4.5) is satisfied

su (4.9) = 0.25329952

Mu = MRc (4.14) = 5.9930E+007

u = su (4.1) = 3.4011160E-005

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.30356779

lb = 300.00

ld = 988.2471

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 20.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 4.61999

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 = 170.00

n = 8.00

Calculation of Mu2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 3.4011160E-005
Mu = 5.9930E+007

with full section properties:

b = 500.00

d = 207.00

d' = 43.00

v = 0.00225456

N = 4666.932

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01464474$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01464474$

$we ((5.4c), TBDY) = ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.07762821$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.07705054

af = 0.45253333

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

bw = 500.00

effective stress from (A.35), $ff_e = 837.9178$

fy = 0.12936483

af = 0.45253333

b = 250.00

h = 500.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

bw = 250.00

effective stress from (A.35), $ff_e = 703.4155$

R = 40.00

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = 0.03751166

bo = 440.00

ho = 190.00

bi2 = 459400.00

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.001848$

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)

$psh_x (5.4d) = 0.001848$

Ash = Astir * ns = 78.53982

No stirrups, ns = 2.00

bk = 500.00

$psh_y (5.4d) = 0.00369599$

Ash = Astir * ns = 78.53982

No stirrups, ns = 2.00

bk = 250.00

s = 170.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$

c = confinement factor = 1.13916

y1 = 0.00130695

sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695

sh2 = 0.00451687

ft2 = 376.4017

fy2 = 313.6681

su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695

shv = 0.00451687

ftv = 376.4017

fyv = 313.6681

suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764

2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764

v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401

and confined core properties:

b = 440.00

d = 177.00

d' = 13.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987

2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987

v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.25329952

Mu = MRc (4.14) = 5.9930E+007

u = su (4.1) = 3.4011160E-005

Calculation of ratio lb/d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 170.00$

$n = 8.00$

Calculation of μ_2 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 3.4011160E-005$

$\mu = 5.9930E+007$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00225456$

$N = 4666.932$

$f_c = 20.00$

α (5A.5, TBDY) = 0.002

Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu, \alpha) = 0.01464474$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu = 0.01464474$

where ((5.4c), TBDY) = $\alpha * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$

where $f = \alpha * \rho * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.07705054$

$\alpha = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\rho = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$

$\alpha = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $\rho = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

α ((5.4d), TBDY) = 0.03751166

$b_o = 440.00$

$h_o = 190.00$

$$bi2 = 459400.00$$

$$psh,min = \text{Min}(psh,x, psh,y) = 0.001848$$

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)

$$psh,x (5.4d) = 0.001848$$

$$Ash = Astir*ns = 78.53982$$

$$\text{No stirrups, } ns = 2.00$$

$$bk = 500.00$$

$$psh,y (5.4d) = 0.00369599$$

$$Ash = Astir*ns = 78.53982$$

$$\text{No stirrups, } ns = 2.00$$

$$bk = 250.00$$

$$s = 170.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y1 = 0.00130695$$

$$sh1 = 0.00451687$$

$$ft1 = 376.4017$$

$$fy1 = 313.6681$$

$$su1 = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/l_d = 0.30356779$$

$$su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 313.6681$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00130695$$

$$sh2 = 0.00451687$$

$$ft2 = 376.4017$$

$$fy2 = 313.6681$$

$$su2 = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/l_{b,min} = 0.30356779$$

$$su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y2, sh2,ft2,fy2, are also multiplied by $\text{Min}(1, 1.25*(lb/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 313.6681$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00130695$$

$$shv = 0.00451687$$

$$ftv = 376.4017$$

$$fyv = 313.6681$$

$$suv = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/l_d = 0.30356779$$

$$suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$$

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 $\text{Min}(1, 1.25*(lb/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 313.6681$
with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1256764$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1256764$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.06093401$

and confined core properties:

$b = 440.00$
 $d = 177.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $c_c (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16701987$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.16701987$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08097933$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->
 $su (4.9) = 0.25329952$
 $Mu = MRc (4.14) = 5.9930E+007$
 $u = su (4.1) = 3.4011160E-005$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.30356779$

$l_b = 300.00$
 $l_d = 988.2471$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1

$db = 18.00$
Mean strength value of all re-bars: $f_y = 555.55$
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$
where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis
 $s = 170.00$
 $n = 8.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 265235.248$

Calculation of Shear Strength at edge 1, $V_{r1} = 265235.248$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$
 $V_{Col0} = 265235.248$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_{s+} = f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $Mu = 2.3992784E-012$
 $Vu = 2.9007121E-031$
 $d = 0.8 * h = 200.00$
 $Nu = 4666.932$
 $Ag = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 49279.392$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 170.00$$

V_s is multiplied by $\text{Col} = 0.60$

$$s/d = 0.85$$

$$V_f \text{ ((11-3)-(11.4), ACI 440) } = 109072.851$$

$f = 0.95$, 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: $\theta = b_1 + 90^\circ = 90.00$

$$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|), \text{ with:}$$

total thickness per orientation, $t_{f1} = N_L * t / \text{NoDir} = 1.016$

$$d_{fv} = d \text{ (figure 11.2, ACI 440) } = 207.00$$

$$f_{fe} \text{ ((11-5), ACI 440) } = 259.312$$

$$E_f = 64828.00$$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$

$$b_w = 500.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 265235.248$

$$V_{r2} = V_{\text{Col}} \text{ ((10.3), ASCE 41-17) } = k_{nl} * V_{\text{Col}0}$$

$$V_{\text{Col}0} = 265235.248$$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$\rho = 1$ (normal-weight concrete)

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$M_u = 2.3992784E-012$$

$$V_u = 2.9007121E-031$$

$$d = 0.8 * h = 200.00$$

$$N_u = 4666.932$$

$$A_g = 125000.00$$

From (11.5.4.8), ACI 318-14: $V_s = 49279.392$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 170.00$$

V_s is multiplied by $\text{Col} = 0.60$

$$s/d = 0.85$$

$$V_f \text{ ((11-3)-(11.4), ACI 440) } = 109072.851$$

$f = 0.95$, 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: $\theta = b_1 + 90^\circ = 90.00$

$$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|), \text{ with:}$$

total thickness per orientation, $t_{f1} = N_L * t / \text{NoDir} = 1.016$

$$d_{fv} = d \text{ (figure 11.2, ACI 440) } = 207.00$$

$$f_{fe} \text{ ((11-5), ACI 440) } = 259.312$$

$$E_f = 64828.00$$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$

$$b_w = 500.00$$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\phi = 1.00$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, $f_s = 1.25 * f_{sm} = 555.55$

Section Height, $H = 250.00$
Section Width, $W = 500.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.13916
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, $V_a = 1.3558547E-031$
EDGE -B-
Shear Force, $V_b = -1.3558547E-031$
BOTH EDGES
Axial Force, $F = -4666.932$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{l,ten} = 829.3805$
-Compression: $As_{l,com} = 829.3805$
-Middle: $As_{l,mid} = 402.1239$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.23676754$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96937.922$

with
 $M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 1.4541E+008$
 $M_{u1+} = 1.4541E+008$, 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
 $M_{u1-} = 1.4541E+008$, 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
 $M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 1.4541E+008$
 $M_{u2+} = 1.4541E+008$, 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
 $M_{u2-} = 1.4541E+008$, 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:

$\phi_u = 1.4467178E-005$

$M_u = 1.4541E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00204242$

$N = 4666.932$

$f_c = 20.00$

α (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01464474$

ϕ_{we} ((5.4c), TBDY) = $\alpha \epsilon_s \cdot \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$

where $\phi = \alpha \epsilon_s * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\phi_x = 0.07705054$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.004064$

$b_w = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$\phi_y = 0.12936483$

$\alpha_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$\alpha \epsilon_s$ ((5.4d), TBDY) = 0.03751166

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$

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) = 0.001848
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127

2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127

v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc \text{ (5A.2, TBDY)} = 22.78316$$

$$cc \text{ (5A.5, TBDY)} = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.1603292$$

$$2 = A_{s2,com}/(b*d)*(f_{s2}/f_c) = 0.1603292$$

$$v = A_{s,mid}/(b*d)*(f_{sv}/f_c) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u \text{ (4.9)} = 0.20486988$$

$$\mu_u = M_{Rc} \text{ (4.14)} = 1.4541E+008$$

$$u = s_u \text{ (4.1)} = 1.4467178E-005$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.30356779$

$$l_b = 300.00$$

$$l_d = 988.2471$$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

$$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$$

where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis

$$s = 170.00$$

$$n = 8.00$$

Calculation of μ_u

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.4467178E-005$$

$$\mu_u = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464474$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01464474$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

h = 250.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$
bw = 500.00
effective stress from (A.35), $ff,e = 837.9178$

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

R = 40.00
Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.001848
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) = 0.001848
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by $Min(1,1.25*(lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs1 = fs = 313.6681$
with $Es1 = Es = 200000.00$
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $es_{u2_nominal} = 0.08$,

For calculation of $es_{u2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fs_{y2} = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 313.6681$

with $Es_2 = Es = 200000.00$

$y_v = 0.00130695$

$sh_v = 0.00451687$

$ft_v = 376.4017$

$fy_v = 313.6681$

$s_{uv} = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$

and also multiplied by the $shear_factor$ according to 15.7.1.4, with

$Shear_factor = 1.00$

$lo/lo_{u,min} = lb/d = 0.30356779$

$s_{uv} = 0.4 \cdot es_{uv_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,

considering characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY

For calculation of $es_{uv_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_v = fs = 313.6681$

with $Es_v = Es = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.11385127$

2 = $As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.11385127$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.05520062$

and confined core properties:

$b = 190.00$

$d = 427.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 22.78316$

$cc (5A.5, TBDY) = 0.00339158$

$c = \text{confinement factor} = 1.13916$

1 = $As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.1603292$

2 = $As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.1603292$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.07773537$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$s_u (4.9) = 0.20486988$

$\mu_u = MR_c (4.14) = 1.4541E+008$

$u = s_u (4.1) = 1.4467178E-005$

Calculation of ratio lb/d

Lap Length: $lb/d = 0.30356779$

$lb = 300.00$

$ld = 988.2471$

Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 18.00$

Mean strength value of all re-bars: $fy = 555.55$

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

$s = 170.00$

$n = 8.00$

Calculation of Mu2+

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.4467178E-005$$

$$Mu = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

$$co \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, cc) = 0.01464474$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.01464474$$

$$\mu_e \text{ ((5.4c), TBDY)} = a_{se} * \frac{sh_{,min} * f_{ywe}}{f_{ce}} + \text{Min}(f_x, f_y) = 0.07762821$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.001848$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00369599$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127

2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127

v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062

and confined core properties:

b = 190.00

d = 427.00

d' = 13.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1603292

2 = Asl,com/(b*d)*(fs2/fc) = 0.1603292

v = Asl,mid/(b*d)*(fsv/fc) = 0.07773537

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

v < vs,y2 - LHS eq.(4.5) is satisfied

---->

su (4.9) = 0.20486988
Mu = MRc (4.14) = 1.4541E+008
u = su (4.1) = 1.4467178E-005

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.30356779

lb = 300.00

l_d = 988.2471

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 20.00, but fc^{0.5} ≤ 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

K_{tr} = 4.61999

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 = 170.00

n = 8.00

Calculation of Mu₂-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.4467178E-005

Mu = 1.4541E+008

with full section properties:

b = 250.00

d = 457.00

d' = 43.00

v = 0.00204242

N = 4666.932

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01464474

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01464474

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.07762821

where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.07705054

af = 0.45253333

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.004064

bw = 500.00

effective stress from (A.35), ff,e = 837.9178

fy = 0.12936483

af = 0.45253333

b = 250.00

h = 500.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128

bw = 250.00

effective stress from (A.35), ff,e = 703.4155

R = 40.00

Effective FRP thickness, tf = NL*t*Cos(b1) = 1.016

$f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase \text{ ((5.4d), TBDY)} = 0.03751166$
 $bo = 440.00$
 $ho = 190.00$
 $bi2 = 459400.00$

$psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.001848$

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)

 $psh_{,x} \text{ (5.4d)} = 0.001848$
 $A_{sh} = A_{stir} * n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $bk = 500.00$

 $psh_{,y} \text{ (5.4d)} = 0.00369599$
 $A_{sh} = A_{stir} * n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $bk = 250.00$

 $s = 170.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$

$y_1 = 0.00130695$
 $sh_1 = 0.00451687$
 $ft_1 = 376.4017$
 $fy_1 = 313.6681$
 $su_1 = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lo_{,min} = lb/ld = 0.30356779$

$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 313.6681$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00130695$
 $sh_2 = 0.00451687$
 $ft_2 = 376.4017$
 $fy_2 = 313.6681$
 $su_2 = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lo_{,min} = lb/lb_{,min} = 0.30356779$

$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 313.6681$

with $Es_2 = Es = 200000.00$

$y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $suv = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lo_{,min} = lb/ld = 0.30356779$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_nominal$ and yv , shv,ftv,fyv , it is considered characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1$, $sh1,ft1,fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 313.6681$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.11385127$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.11385127$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.05520062$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.1603292$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.1603292$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < vs,y2$ - LHS eq.(4.5) is satisfied

$$su (4.9) = 0.20486988$$

$$\text{Mu} = \text{MRc} (4.14) = 1.4541\text{E}+008$$

$$u = su (4.1) = 1.4467178\text{E}-005$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$

$$lb = 300.00$$

$$ld = 988.2471$$

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$db = 18.00$$

Mean strength value of all re-bars: $fy = 555.55$

$$fc' = 20.00, \text{ but } fc'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$Ktr = 4.61999$$

$$Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$$

where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis

$$s = 170.00$$

$$n = 8.00$$

Calculation of Shear Strength $Vr = \text{Min}(Vr1, Vr2) = 409422.352$

Calculation of Shear Strength at edge 1, $Vr1 = 409422.352$

$$Vr1 = VCol ((10.3), ASCE 41-17) = knl * VCol0$$

$$VCol0 = 409422.352$$

$$knl = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) ' $Vs = Av * fy * d / s$ ' is replaced by ' $Vs + f * Vf$ '
where Vf is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$fc' = 20.00, \text{ but } fc'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$\mu_u = 2.8180236E-013$
 $V_u = 1.3558547E-031$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 164264.64$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.425$
 V_f ((11-3)-(11.4), ACI 440) = 240803.347
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 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: $V_s + V_f \leq 297085.704$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 409422.352$
 $V_{r2} = V_{\text{Col}}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{\text{Col}0}$
 $V_{\text{Col}0} = 409422.352$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$\mu_c = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 2.8180236E-013$
 $V_u = 1.3558547E-031$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 164264.64$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.425$
 V_f ((11-3)-(11.4), ACI 440) = 240803.347
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 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: $V_s + V_f \leq 297085.704$
 $bw = 250.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
At local axis: 2
Integration Section: (b)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\phi = 1.00$
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$
Section Height, $H = 250.00$
Section Width, $W = 500.00$
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, $NoDir = 1$
Fiber orientations, $bi = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 6.0169508E-011$
Shear Force, $V_2 = 4708.27$
Shear Force, $V_3 = 3.5022564E-013$
Axial Force, $F = -4886.081$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 829.3805$
-Compression: $As_{c,com} = 829.3805$
-Middle: $As_{mid} = 402.1239$
Mean Diameter of Tension Reinforcement, $Db_L = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $\phi_{u,R} = \phi_u = 0.04410058$

$$u = y + p = 0.04410058$$

- Calculation of y -

$$y = (M_y * L_s / 3) / E_{eff} = 0.00620957 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 5.0984E+007$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 1500.00$$

$$\text{From table 10.5, ASCE 41_17: } E_{eff} = \text{factor} * E_c * I_g = 4.1053E+012$$

$$\text{factor} = 0.30$$

$$A_g = 125000.00$$

$$f_c' = 20.00$$

$$N = 4886.081$$

$$E_c * I_g = 1.3684E+013$$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$$y = \text{Min}(y_{ten}, y_{com})$$

$$y_{ten} = 1.0451750E-005$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / d)^{2/3}) = 291.1836$$

$$d = 207.00$$

$$y = 0.32705805$$

$$A = 0.02007406$$

$$B = 0.01218624$$

$$\text{with } p_t = 0.00801334$$

$$p_c = 0.00801334$$

$$p_v = 0.00388525$$

$$N = 4886.081$$

$$b = 500.00$$

$$" = 0.20772947$$

$$y_{comp} = 2.5957131E-005$$

$$\text{with } f_c' \text{ (12.3, (ACI 440))} = 20.44529$$

$$f_c = 20.00$$

$$f_l = 0.9425867$$

$$b = 500.00$$

$$h = 250.00$$

$$A_g = 125000.00$$

$$\text{From (12.9), ACI 440: } k_a = 0.1506892$$

$$g = p_t + p_c + p_v = 0.01991193$$

$$r_c = 40.00$$

$$A_e / A_c = 0.60275679$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(\theta_1) = 1.016$$

$$\text{effective strain from (12.5) and (12.12), } \epsilon_{fe} = 0.004$$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 21019.039$$

$$y = 0.32585609$$

$$A = 0.01977712$$

$$B = 0.01202411$$

$$\text{with } E_s = 200000.00$$

Calculation of ratio l_b / d

$$\text{Lap Length: } l_d / d, \text{min} = 0.37945973$$

$$l_b = 300.00$$

$$l_d = 790.5977$$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

$$\text{Mean strength value of all re-bars: } f_y = 444.44$$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 4.61999
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 = 170.00
n = 8.00

- Calculation of ρ -

From table 10-8: $\rho = 0.03789101$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$
shear control ratio $V_y E / V_{CoI} E = 0.15063296$

d = 207.00

s = 0.00

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$

$A_v = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$b_w = 500.00$

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 = 4886.081

$A_g = 125000.00$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.01991193$

b = 500.00

d = 207.00

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 15

column C1, Floor 1

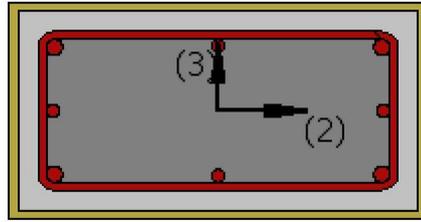
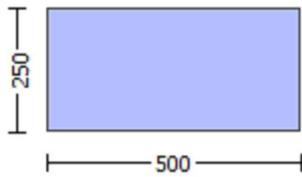
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

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, $M_a = 9.9150700E-010$

Shear Force, $V_a = -3.5022564E-013$

EDGE -B-

Bending Moment, $M_b = 6.0169508E-011$

Shear Force, $V_b = 3.5022564E-013$
 BOTH EDGES
 Axial Force, $F = -4886.081$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 0.00$
 -Compression: $As_c = 2060.885$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{t,ten} = 829.3805$
 -Compression: $As_{c,com} = 829.3805$
 -Middle: $As_{mid} = 402.1239$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 248589.15$
 V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoL} = 248589.15$
 $V_{CoL} = 248589.15$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.00$

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + \phi \cdot V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 $f'_c = 16.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 6.0169508E-011$
 $V_u = 3.5022564E-013$
 $d = 0.8 \cdot h = 200.00$
 $N_u = 4886.081$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 44351.896$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 170.00$

V_s is multiplied by $\phi_{CoL} = 0.60$
 $s/d = 0.85$

V_f ((11-3)-(11.4), ACI 440) = 109072.851
 $\phi = 0.95$, 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 $(\cot \theta + \csc \theta) \sin \theta$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation θ_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 207.00

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: $V_s + V_f \leq 265721.532$

$b_w = 500.00$

$displacement_ductility_demand$ is calculated as δ / y

- Calculation of δ / y for END B -
 for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 3.2103728E-020$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00620957$ ((4.29), Biskinis Phd)
 $M_y = 5.0984E+007$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1053E+012$

factor = 0.30

$A_g = 125000.00$

$f_c' = 20.00$

$N = 4886.081$

$E_c * I_g = 1.3684E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 1.0451750E-005$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / l_d)^{2/3}) = 291.1836$

$d = 207.00$

$y = 0.32705805$

$A = 0.02007406$

$B = 0.01218624$

with $p_t = 0.00801334$

$p_c = 0.00801334$

$p_v = 0.00388525$

$N = 4886.081$

$b = 500.00$

$" = 0.20772947$

$y_{comp} = 2.5957131E-005$

with $f_c' (12.3, (ACI 440)) = 20.44529$

$f_c = 20.00$

$f_l = 0.9425867$

$b = 500.00$

$h = 250.00$

$A_g = 125000.00$

From (12.9), ACI 440: $k_a = 0.1506892$

$g = p_t + p_c + p_v = 0.01991193$

$r_c = 40.00$

$A_e / A_c = 0.60275679$

Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$

effective strain from (12.5) and (12.12), $e_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 21019.039$

$y = 0.32585609$

$A = 0.01977712$

$B = 0.01202411$

with $E_s = 200000.00$

Calculation of ratio l_b / l_d

Lap Length: $l_d / l_d, \text{min} = 0.37945973$

$l_b = 300.00$

$l_d = 790.5977$

Calculation of I according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

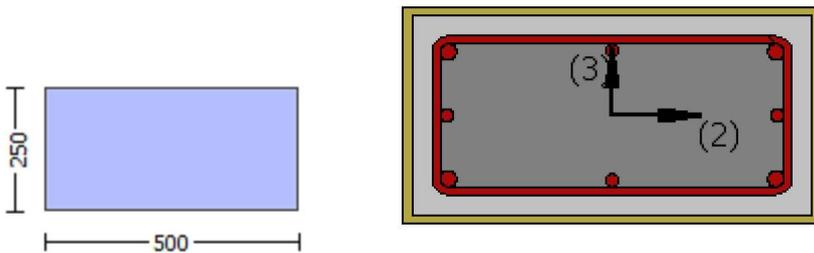
$s = 170.00$

n = 8.00

End Of Calculation of Shear Capacity for element: column C1 of floor 1
At local axis: 3
Integration Section: (b)

Calculation No. 16

column C1, Floor 1
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)
Analysis: Uniform +X
Check: Chord rotation capacity (θ)
Edge: End
Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At Shear local axis: 3
(Bending local axis: 2)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

Section Height, $H = 250.00$
Section Width, $W = 500.00$
Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916
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 = 2.9007121E-031
EDGE -B-
Shear Force, V_b = -2.9007121E-031
BOTH EDGES
Axial Force, F = -4666.932
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t}$ = 0.00
-Compression: $A_{sl,c}$ = 2060.885
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten}$ = 829.3805
-Compression: $A_{sl,com}$ = 829.3805
-Middle: $A_{sl,mid}$ = 402.1239

Calculation of Shear Capacity ratio , V_e/V_r = 0.15063296

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 39953.171$
with

$M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 5.9930E+007$

$\mu_{u1+} = 5.9930E+007$, 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

$\mu_{u1-} = 5.9930E+007$, 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

$M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 5.9930E+007$

$\mu_{u2+} = 5.9930E+007$, 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

$\mu_{u2-} = 5.9930E+007$, 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 according to 4.1, Biskinis/Fardis 2013:

$\mu = 3.4011160E-005$

$\mu_u = 5.9930E+007$

with full section properties:

$b = 500.00$

d = 207.00

d' = 43.00

v = 0.00225456

N = 4666.932

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01464474$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01464474$

we ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.07762821$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.07705054

af = 0.45253333

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

bw = 500.00

effective stress from (A.35), $ff_e = 837.9178$

fy = 0.12936483

af = 0.45253333

b = 250.00

h = 500.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

bw = 250.00

effective stress from (A.35), $ff_e = 703.4155$

R = 40.00

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = 0.03751166

bo = 440.00

ho = 190.00

bi2 = 459400.00

psh,min = $\text{Min}(psh_x, psh_y) = 0.001848$

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) = 0.001848

Ash = $A_{stir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 500.00

psh,y (5.4d) = 0.00369599

Ash = $A_{stir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 250.00

s = 170.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$

c = confinement factor = 1.13916

y1 = 0.00130695

sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = $lb/d = 0.30356779$

su1 = $0.4 * esu1_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08,$

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 313.6681$

with $Es1 = Es = 200000.00$

$y2 = 0.00130695$

$sh2 = 0.00451687$

$ft2 = 376.4017$

$fy2 = 313.6681$

$su2 = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lo_{u,min} = lb/lb_{min} = 0.30356779$

$su2 = 0.4 \cdot esu2_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 313.6681$

with $Es2 = Es = 200000.00$

$yv = 0.00130695$

$shv = 0.00451687$

$ftv = 376.4017$

$fyv = 313.6681$

$suv = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lo_{u,min} = lb/ld = 0.30356779$

$suv = 0.4 \cdot esuv_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fsv = fs = 313.6681$

with $Esv = Es = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (fs1/fc) = 0.1256764$

2 = $Asl_{com}/(b \cdot d) \cdot (fs2/fc) = 0.1256764$

v = $Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.06093401$

and confined core properties:

$b = 440.00$

$d = 177.00$

$d' = 13.00$

f_{cc} (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = $Asl_{ten}/(b \cdot d) \cdot (fs1/fc) = 0.16701987$

2 = $Asl_{com}/(b \cdot d) \cdot (fs2/fc) = 0.16701987$

v = $Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.08097933$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.25329952

$Mu = MRc$ (4.14) = 5.9930E+007

$u = su$ (4.1) = 3.4011160E-005

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$

$lb = 300.00$

$ld = 988.2471$

Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

s = 170.00

n = 8.00

Calculation of μ_1 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 3.4011160E-005$

$\mu_u = 5.9930E+007$

with full section properties:

b = 500.00

d = 207.00

$d' = 43.00$

$v = 0.00225456$

N = 4666.932

$f_c = 20.00$

α (5A.5, TBDY) = 0.002

Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.01464474$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_u = 0.01464474$

μ_{ve} ((5.4c), TBDY) = $\alpha s_e * \text{sh}_{\min} * f_{yve} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$

where $f = \alpha f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07705054$

$\alpha f = 0.45253333$

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.004064$

$b_w = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

 $f_y = 0.12936483$

$\alpha f = 0.45253333$

b = 250.00

h = 500.00

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

R = 40.00

Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

αs_e ((5.4d), TBDY) = 0.03751166

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$

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) = 0.001848
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb,min)^ 2/3), from 10.3.5, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y2, sh2,ft2,fy2, are also multiplied by Min(1,1.25*(lb/lb,min)^ 2/3), from 10.3.5, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb,min)^ 2/3), from 10.3.5, ASCE41-17.

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764
2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764
v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$fcc \text{ (5A.2, TBDY)} = 22.78316$$

$$cc \text{ (5A.5, TBDY)} = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.16701987$$

$$2 = A_{s2,com}/(b*d)*(f_{s2}/f_c) = 0.16701987$$

$$v = A_{s,mid}/(b*d)*(f_{sv}/f_c) = 0.08097933$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u \text{ (4.9)} = 0.25329952$$

$$M_u = M_{Rc} \text{ (4.14)} = 5.9930E+007$$

$$u = s_u \text{ (4.1)} = 3.4011160E-005$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.30356779$

$$l_b = 300.00$$

$$l_d = 988.2471$$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

$$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$$

where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis

$$s = 170.00$$

$$n = 8.00$$

Calculation of M_u2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 3.4011160E-005$$

$$M_u = 5.9930E+007$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00225456$$

$$N = 4666.932$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464474$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01464474$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e^* s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

h = 250.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$
bw = 500.00
effective stress from (A.35), $ff,e = 837.9178$

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

R = 40.00
Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.001848
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) = 0.001848
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by $Min(1,1.25*(lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs1 = fs = 313.6681$
with $Es1 = Es = 200000.00$
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $es_{u2_nominal} = 0.08$,

For calculation of $es_{u2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fs_{y2} = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 313.6681$

with $Es_2 = Es = 200000.00$

$y_v = 0.00130695$

$sh_v = 0.00451687$

$ft_v = 376.4017$

$fy_v = 313.6681$

$s_{uv} = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$

and also multiplied by the $shear_factor$ according to 15.7.1.4, with

$Shear_factor = 1.00$

$lo/lo_{u,min} = lb/d = 0.30356779$

$s_{uv} = 0.4 \cdot es_{uv_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,

considering characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY

For calculation of $es_{uv_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_v = fs = 313.6681$

with $Es_v = Es = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.1256764$

2 = $As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.1256764$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.06093401$

and confined core properties:

$b = 440.00$

$d = 177.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 22.78316$

$cc (5A.5, TBDY) = 0.00339158$

$c = \text{confinement factor} = 1.13916$

1 = $As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.16701987$

2 = $As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.16701987$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.08097933$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$s_u (4.9) = 0.25329952$

$M_u = MR_c (4.14) = 5.9930E+007$

$u = s_u (4.1) = 3.4011160E-005$

Calculation of ratio lb/d

Lap Length: $lb/d = 0.30356779$

$lb = 300.00$

$ld = 988.2471$

Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 18.00$

Mean strength value of all re-bars: $fy = 555.55$

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

$s = 170.00$

$n = 8.00$

Calculation of Mu2-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 3.4011160E-005$$

$$Mu = 5.9930E+007$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00225456$$

$$N = 4666.932$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_o) = 0.01464474$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.01464474$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s e \text{ ((5.4d), TBDY)} = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.001848$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00369599$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687

ft2 = 376.4017

fy2 = 313.6681

su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695
shv = 0.00451687

ftv = 376.4017

fyv = 313.6681

suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764

2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764

v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401

and confined core properties:

b = 440.00

d = 177.00

d' = 13.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987

2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987

v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.25329952
Mu = MRc (4.14) = 5.9930E+007
u = su (4.1) = 3.4011160E-005

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.30356779

lb = 300.00

ld = 988.2471

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 20.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 4.61999

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 = 170.00

n = 8.00

Calculation of Shear Strength Vr = Min(Vr1, Vr2) = 265235.248

Calculation of Shear Strength at edge 1, Vr1 = 265235.248

Vr1 = VCol ((10.3), ASCE 41-17) = knl*VCol0

VCol0 = 265235.248

knl = 1 (zero step-static loading)

NOTE: In expression (10-3) 'Vs = Av*fy*d/s' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

fc' = 20.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/d = 2.00

Mu = 2.3992784E-012

Vu = 2.9007121E-031

d = 0.8*h = 200.00

Nu = 4666.932

Ag = 125000.00

From (11.5.4.8), ACI 318-14: Vs = 49279.392

Av = 157079.633

fy = 444.44

s = 170.00

Vs is multiplied by Col = 0.60

s/d = 0.85

Vf ((11-3)-(11.4), ACI 440) = 109072.851

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 + cota)sina which is more a generalised expression,

where is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(,), is implemented for every different fiber orientation ai, as well as for 2 crack directions, = 45° and = -45° to take into consideration the cyclic seismic loading.

orientation 1: 1 = b1 + 90° = 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) = 207.00

ffe ((11-5), ACI 440) = 259.312

Ef = 64828.00

fe = 0.004, from (11.6a), ACI 440

with fu = 0.01

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $bw = 500.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 265235.248$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Col0}$
 $V_{Col0} = 265235.248$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M / Vd = 2.00$
 $\mu_u = 2.3992784E-012$
 $\nu_u = 2.9007121E-031$
 $d = 0.8 * h = 200.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 49279.392$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$

V_s is multiplied by $\phi_{col} = 0.60$
 $s/d = 0.85$

V_f ((11-3)-(11.4), ACI 440) = 109072.851
 $f = 0.95$, 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: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \alpha_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 207.00

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: $V_s + V_f \leq 297085.704$
 $bw = 500.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\phi = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

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, $V_a = 1.3558547E-031$

EDGE -B-

Shear Force, $V_b = -1.3558547E-031$

BOTH EDGES

Axial Force, $F = -4666.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{,ten} = 829.3805$

-Compression: $As_{,com} = 829.3805$

-Middle: $As_{,mid} = 402.1239$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.23676754$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96937.922$

with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 1.4541E+008$

$\mu_{1+} = 1.4541E+008$, 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

$\mu_{1-} = 1.4541E+008$, 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 1.4541E+008$

$\mu_{2+} = 1.4541E+008$, 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

$\mu_{2-} = 1.4541E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.4467178E-005$$

$$\mu = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

$$\alpha (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01464474$$

$$\omega_e \text{ ((5.4c), TBDY) } = \alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$$

where $\phi = \alpha * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.07705054$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$\phi_y = 0.12936483$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(\beta_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha s_e \text{ ((5.4d), TBDY) } = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$\text{psh}_{\min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.001848$$

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)

$$\text{psh}_x \text{ (5.4d) } = 0.001848$$

$$A_{sh} = A_{\text{stir}} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$\text{psh}_y \text{ (5.4d) } = 0.00369599$$

$$A_{sh} = A_{\text{stir}} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00130695$$

$$\text{sh}_1 = 0.00451687$$

$$f_{t1} = 376.4017$$

$$f_{y1} = 313.6681$$

$$s_{u1} = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.30356779$$

$$s_u1 = 0.4 * e_{su1,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su1,nominal} = 0.08$,

For calculation of $e_{su1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $f_{sy1} = f_{s1}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s1} = f_s = 313.6681$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.00130695$$

$$sh_2 = 0.00451687$$

$$ft_2 = 376.4017$$

$$fy_2 = 313.6681$$

$$s_u2 = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30356779$$

$$s_u2 = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su2,nominal} = 0.08$,

For calculation of $e_{su2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s2} = f_s = 313.6681$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.00130695$$

$$sh_v = 0.00451687$$

$$ft_v = 376.4017$$

$$fy_v = 313.6681$$

$$s_{uv} = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.30356779$$

$$s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY
For calculation of $e_{suv,nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{sv} = f_s = 313.6681$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.11385127$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.11385127$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.05520062$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.1603292$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.1603292$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.20486988$$

$$\mu_u = M_{Rc} (4.14) = 1.4541E+008$$

$$u = s_u (4.1) = 1.4467178E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 170.00$

$n = 8.00$

Calculation of μ_{u1}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$\mu_u = 1.4467178E-005$

$\mu_u = 1.4541E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00204242$

$N = 4666.932$

$f_c = 20.00$

α_{co} (5A.5, TBDY) = 0.002

Final value of α_{cu} : $\alpha_{cu}^* = \text{shear_factor} * \max(\alpha_{cu}, \alpha_{cc}) = 0.01464474$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\alpha_{cu} = 0.01464474$

where ((5.4c), TBDY) = $\alpha_{se} * \frac{\min(f_{ywe}/f_{ce}, \min(f_x, f_y))}{f_{ce}}$ = 0.07762821

where $f = \alpha_{se} * \frac{p_f * f_{fe}}{f_{ce}}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.07705054$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$

$\alpha_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

α_{se} ((5.4d), TBDY) = 0.03751166

$b_o = 440.00$

ho = 190.00

bi2 = 459400.00

psh,min = Min(psh,x , psh,y) = 0.001848

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) = 0.001848

Ash = Astir*ns = 78.53982

No stirups, ns = 2.00

bk = 500.00

psh,y (5.4d) = 0.00369599

Ash = Astir*ns = 78.53982

No stirups, ns = 2.00

bk = 250.00

s = 170.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158

c = confinement factor = 1.13916

y1 = 0.00130695

sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695

sh2 = 0.00451687

ft2 = 376.4017

fy2 = 313.6681

su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695

shv = 0.00451687

ftv = 376.4017

fyv = 313.6681

suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered

characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 313.6681$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.11385127$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.11385127$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.05520062$

and confined core properties:

$b = 190.00$

$d = 427.00$

$d' = 13.00$

$f_{cc} \text{ (5A.2, TBDY)} = 22.78316$

$cc \text{ (5A.5, TBDY)} = 0.00339158$

$c = \text{confinement factor} = 1.13916$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.1603292$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.1603292$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.07773537$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$su \text{ (4.9)} = 0.20486988$

$Mu = MRc \text{ (4.14)} = 1.4541E+008$

$u = su \text{ (4.1)} = 1.4467178E-005$

Calculation of ratio lb/d

Lap Length: $lb/d = 0.30356779$

$lb = 300.00$

$ld = 988.2471$

Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

$s = 170.00$

$n = 8.00$

Calculation of Mu_{2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 1.4467178E-005$

$Mu = 1.4541E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00204242$

$N = 4666.932$

$f_c = 20.00$

$co \text{ (5A.5, TBDY)} = 0.002$

Final value of cu : $cu^* = \text{shear_factor} \cdot \text{Max}(cu, cc) = 0.01464474$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01464474$

w_e ((5.4c), TBDY) = $a_{se} \cdot s_{h,min} \cdot f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$
where $f = a_f \cdot p_f \cdot f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.07705054$
 $a_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$
From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.004064$
 $bw = 500.00$
effective stress from (A.35), $f_{f,e} = 837.9178$

$f_y = 0.12936483$
 $a_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$
From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.008128$
 $bw = 250.00$
effective stress from (A.35), $f_{f,e} = 703.4155$

$R = 40.00$
Effective FRP thickness, $t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 a_{se} ((5.4d), TBDY) = 0.03751166
 $b_o = 440.00$
 $h_o = 190.00$
 $b_{i2} = 459400.00$
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$
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) = 0.001848
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $b_k = 500.00$

$p_{sh,y}$ (5.4d) = 0.00369599
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $b_k = 250.00$

$s = 170.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$
From ((5.A5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $y_1 = 0.00130695$
 $sh_1 = 0.00451687$
 $ft_1 = 376.4017$
 $fy_1 = 313.6681$
 $su_1 = 0.005257$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30356779$
 $su_1 = 0.4 \cdot esu_{1,nominal}$ ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$
For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs_1 = fs = 313.6681$
with $Es_1 = Es = 200000.00$
 $y_2 = 0.00130695$
 $sh_2 = 0.00451687$
 $ft_2 = 376.4017$
 $fy_2 = 313.6681$

$$su_2 = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/lb_{u,min} = 0.30356779$$

$$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 313.6681$$

$$\text{with } Es_2 = Es = 200000.00$$

$$yv = 0.00130695$$

$$shv = 0.00451687$$

$$ftv = 376.4017$$

$$fyv = 313.6681$$

$$suv = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/ld = 0.30356779$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_{nominal}$ and yv, shv, ftv, fyv , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 313.6681$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.11385127$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.11385127$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.05520062$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.1603292$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.1603292$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs, y_2$ - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.20486988$$

$$\mu = MRc (4.14) = 1.4541E+008$$

$$u = su (4.1) = 1.4467178E-005$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$

$$lb = 300.00$$

$$ld = 988.2471$$

Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$db = 18.00$$

Mean strength value of all re-bars: $fy = 555.55$

$fc' = 20.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 4.61999$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 170.00$$

$$n = 8.00$$

Calculation of μ_2 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.4467178E-005$$

$$\mu_2 = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_c: \mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01464474$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_c = 0.01464474$$

$$\mu_{cc} \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(\beta_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,\text{min}} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.001848$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00369599$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$s = 170.00$
 $fy_{we} = 555.55$
 $f_{ce} = 20.00$
 From ((5.A.5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $y_1 = 0.00130695$
 $sh_1 = 0.00451687$
 $ft_1 = 376.4017$
 $fy_1 = 313.6681$
 $su_1 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 0.30356779$
 $su_1 = 0.4 * esu_1 \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esu_1 \text{ nominal} = 0.08$,
 For calculation of $esu_1 \text{ nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 313.6681$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.00130695$
 $sh_2 = 0.00451687$
 $ft_2 = 376.4017$
 $fy_2 = 313.6681$
 $su_2 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/lb, \min = 0.30356779$
 $su_2 = 0.4 * esu_2 \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esu_2 \text{ nominal} = 0.08$,
 For calculation of $esu_2 \text{ nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 313.6681$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 0.30356779$
 $suv = 0.4 * esuv \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esuv \text{ nominal} = 0.08$,
 considering characteristic value $fsyv = fs_v/1.2$, from table 5.1, TBDY
 For calculation of $esuv \text{ nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fs_v/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_v = fs = 313.6681$
 with $Es_v = Es = 200000.00$
 $1 = Asl, \text{ten}/(b * d) * (fs_1/fc) = 0.11385127$
 $2 = Asl, \text{com}/(b * d) * (fs_2/fc) = 0.11385127$
 $v = Asl, \text{mid}/(b * d) * (fs_v/fc) = 0.05520062$
 and confined core properties:
 $b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $f_{cc} \text{ (5A.2, TBDY)} = 22.78316$
 $cc \text{ (5A.5, TBDY)} = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl, \text{ten}/(b * d) * (fs_1/fc) = 0.1603292$
 $2 = Asl, \text{com}/(b * d) * (fs_2/fc) = 0.1603292$

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u(4.9) = 0.20486988$$

$$M_u = M_{Rc}(4.14) = 1.4541E+008$$

$$u = s_u(4.1) = 1.4467178E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$$l_b = 300.00$$

$$l_d = 988.2471$$

Calculation of l_b, min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 170.00$$

$$n = 8.00$$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 409422.352$

Calculation of Shear Strength at edge 1, $V_{r1} = 409422.352$

$$V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} \cdot V_{Col0}$$

$$V_{Col0} = 409422.352$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$M_u = 2.8180236E-013$$

$$V_u = 1.3558547E-031$$

$$d = 0.8 \cdot h = 400.00$$

$$N_u = 4666.932$$

$$A_g = 125000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 164264.64$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 170.00$$

$$V_s \text{ is multiplied by } C_{ol} = 1.00$$

$$s/d = 0.425$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 240803.347$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$$w_f/s_f = 1 \text{ (FRP strips adjacent to one another).}$$

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.

$$\text{orientation 1: } \theta = 45^\circ + 90^\circ = 135^\circ$$

$$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|), \text{ with:}$$

total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 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: $V_s + V_f \leq 297085.704$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 409422.352$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 409422.352$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M / Vd = 2.00$
 $\mu_u = 2.8180236E-013$
 $V_u = 1.3558547E-031$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 164264.64$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$

V_s is multiplied by $Col = 1.00$
 $s/d = 0.425$

V_f ((11-3)-(11.4), ACI 440) = 240803.347
 $f = 0.95$, 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 cyclic fiber orientation a_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 457.00

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: $V_s + V_f \leq 297085.704$

$b_w = 250.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
At local axis: 3
Integration Section: (b)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Section Height, $H = 250.00$

Section Width, $W = 500.00$

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, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 117197.472$

Shear Force, $V_2 = 4708.27$

Shear Force, $V_3 = 3.5022564E-013$

Axial Force, $F = -4886.081$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 829.3805$

-Compression: $A_{sl,com} = 829.3805$

-Middle: $A_{sl,mid} = 402.1239$

Mean Diameter of Tension Reinforcement, $DbL = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $\phi_{u,R} = \phi_u = 0.04269636$

$\phi_u = \phi_y + \phi_p = 0.04269636$

- Calculation of ϕ_y -

$\phi_y = (M_y * L_s / 3) / E_{eff} = 0.00069636$ ((4.29), Biskinis Phd))

$M_y = 1.1435E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.6421E+013$

factor = 0.30

$A_g = 125000.00$

$f_c' = 20.00$

$N = 4886.081$

$E_c * I_g = 5.4737E+013$

Calculation of Yielding Moment M_y

Calculation of ϕ_y and M_y according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 4.5289398\text{E}-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 291.1836$
 $d = 457.00$
 $y = 0.29656463$
 $A = 0.01818525$
 $B = 0.01001469$
 with $pt = 0.00725935$
 $pc = 0.00725935$
 $pv = 0.00351968$
 $N = 4886.081$
 $b = 250.00$
 $" = 0.0940919$
 $y_{\text{comp}} = 1.2978922\text{E}-005$
 with fc^* (12.3, (ACI 440)) = 20.44585
 $fc = 20.00$
 $fl = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $Ag = 125000.00$
 From (12.9), ACI 440: $ka = 0.15087868$
 $g = pt + pc + pv = 0.01803838$
 $rc = 40.00$
 $Ae/Ac = 0.60351471$
 Effective FRP thickness, $tf = NL \cdot t \cdot \text{Cos}(b1) = 1.016$
 effective strain from (12.5) and (12.12), $efe = 0.004$
 $fu = 0.01$
 $Ef = 64828.00$
 $Ec = 21019.039$
 $y = 0.29519565$
 $A = 0.01791625$
 $B = 0.00986782$
 with $Es = 200000.00$

Calculation of ratio l_b/d

Lap Length: $l_d/l_d, \text{min} = 0.37945973$
 $l_b = 300.00$
 $l_d = 790.5977$
 Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $f_y = 444.44$
 $fc' = 20.00$, but $fc^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

- Calculation of p -

From table 10-8: $p = 0.042$
 with:
 - Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$
 shear control ratio $V_y E / V_{col} O E = 0.23676754$
 $d = 457.00$
 $s = 0.00$
 $t = A_v / (b_w \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00$

$A_v = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$b_w = 250.00$

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ is implemented to account for FRP contribution

where $f = 2 \cdot t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

$N_{UD} = 4886.081$

$A_g = 125000.00$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.01803838$

$b = 250.00$

$d = 457.00$

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (b)
