

Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

column C1, Floor 1

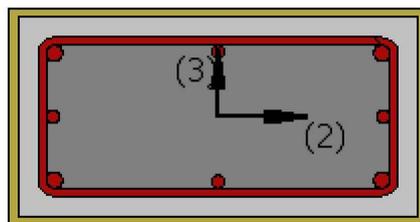
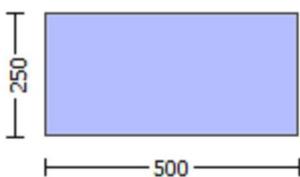
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity 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, $\gamma = 0.85$

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

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

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 20.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 420.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

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

New material: Concrete Strength, $f_c = f_{cm} = 30.00$

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

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Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -1.1312E+007$

Shear Force, $V_a = -3769.985$

EDGE -B-

Bending Moment, $M_b = -0.00064216$

Shear Force, $V_b = 3769.985$

BOTH EDGES

Axial Force, $F = -4665.423$

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, $Db_{L,ten} = 18.66667$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0 \cdot V_n = 353253.878$

V_n ((10.3), ASCE 41-17) = $kn_l \cdot V_{CoI} = 353253.878$

$V_{CoI} = 353253.878$

$kn_l = 1.00$

displacement_ductility_demand = 0.01505362

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)

$M/Vd = 4.00$

$M_u = 1.1312E+007$

$V_u = 3769.985$

$d = 0.8 \cdot h = 400.00$
 $Nu = 4665.423$
 $Ag = 125000.00$
 From (11.5.4.8), ACI 318-14: $Vs = 263893.783$
 $Av = 157079.633$
 $fy = 420.00$
 $s = 100.00$
 Vs is multiplied by $Col = 1.00$
 $s/d = 0.25$
 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 $Vf(\alpha, \theta)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, \theta)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / \text{NoDir} = 1.016$
 $dfv = d$ (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: $Vs + Vf \leq 297085.704$
 $bw = 250.00$

 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 $\theta = 0.00015499$
 $y = (My \cdot Ls / 3) / Eleff = 0.01029579$ ((4.29), Biskinis Phd))
 $My = 2.0703E+008$
 $Ls = M/V$ (with $Ls > 0.1 \cdot L$ and $Ls < 2 \cdot L$) = 3000.571
 From table 10.5, ASCE 41_17: $Eleff = \text{factor} \cdot Ec \cdot Ig = 2.0112E+013$
 $\text{factor} = 0.30$
 $Ag = 125000.00$
 $fc' = 30.00$
 $N = 4665.423$
 $Ec \cdot Ig = 6.7039E+013$

 Calculation of Yielding Moment My

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

 $y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 7.9424740E-006$
 with $fy = 525.00$
 $d = 457.00$
 $y = 0.27680185$
 $A = 0.01811616$
 $B = 0.0099456$
 with $pt = 0.00725935$
 $pc = 0.00725935$
 $pv = 0.00351968$
 $N = 4665.423$
 $b = 250.00$
 $\theta = 0.0940919$
 $y_{comp} = 1.6862746E-005$
 with $fc' = 30.00$ (12.3, (ACI 440)) = 30.44585
 $fc = 30.00$

$f_l = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $A_g = 125000.00$
 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, $t_f = NL * t * \cos(\theta) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 25742.96$
 $y = 0.27624702$
 $A = 0.01794247$
 $B = 0.00986782$
 with $E_s = 200000.00$

Calculation of ratio I_b/I_d

Adequate Lap Length: $I_b/I_d \geq 1$

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

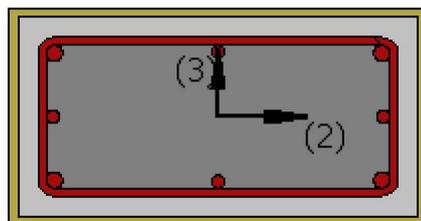
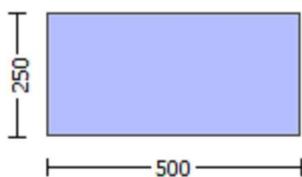
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_r)

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, $\phi = 0.85$
Mean strength values are used for both shear and moment calculations.
Consequently:
New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$
Concrete Elasticity, $E_c = 25742.96$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 656.25$

Section Height, $H = 250.00$
Section Width, $W = 500.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.09431
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou}, \min >= 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
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, $V_a = -1.0405794E-032$
EDGE -B-
Shear Force, $V_b = 1.0405794E-032$
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, $V_e/V_r = 0.21712381$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 88136.71$
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.3221E+008$

Mu1+ = 1.3221E+008, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

Mu1- = 1.3221E+008, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

Mpr2 = Max(Mu2+ , Mu2-) = 1.3221E+008

Mu2+ = 1.3221E+008, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

Mu2- = 1.3221E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu1+

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

$\phi_u = 0.0002015$

Mu = 1.3221E+008

with full section properties:

b = 500.00

d = 207.00

d' = 43.00

v = 0.00150304

N = 4666.932

fc = 30.00

co (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01290198$

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

From (5.4b), TBDY: $\phi_u = 0.01290198$

ϕ_{we} ((5.4c), TBDY) = $\text{ase} * \text{sh}_{\min} * \phi_{we} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.05524832$

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

 $\phi_x = 0.0541155$

$\text{af} = 0.45253333$

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), $\phi_{fe} = 882.7518$

 $\phi_y = 0.09723711$

$\text{af} = 0.45253333$

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), $\phi_{fe} = 793.0837$

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) = 0.05494666

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$\text{psh}_{\min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.00314159$

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) = 0.00314159

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

No stirrups, $n_s = 2.00$

$b_k = 500.00$

psh,y (5.4d) = 0.00628319
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431

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

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

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

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

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

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

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

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

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

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

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

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

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

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

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

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

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

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

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

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

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

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

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

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

with fsv = fs = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17529176

2 = Asl,com/(b*d)*(fs2/fc) = 0.17529176

v = Asl,mid/(b*d)*(fsv/fc) = 0.08498995

and confined core properties:

b = 440.00

d = 177.00

d' = 13.00

fcc (5A.2, TBDY) = 32.82928

$$cc \text{ (5A.5, TBDY)} = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = \text{Asl,ten}/(b*d)*(fs1/fc) = 0.23295708$$

$$2 = \text{Asl,com}/(b*d)*(fs2/fc) = 0.23295708$$

$$v = \text{Asl,mid}/(b*d)*(fsv/fc) = 0.11294889$$

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

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

--->

$$su \text{ (4.9)} = 0.23279566$$

$$Mu = MRc \text{ (4.14)} = 1.3221E+008$$

$$u = su \text{ (4.1)} = 0.0002015$$

Calculation of ratio l_b/l_d

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

Calculation of Mu_1 -

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

$$u = 0.0002015$$

$$Mu = 1.3221E+008$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00150304$$

$$N = 4666.932$$

$$fc = 30.00$$

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

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01290198$$

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

$$\text{From (5.4b), TBDY: } cu = 0.01290198$$

$$we \text{ ((5.4c), TBDY)} = ase * sh_{,min} * fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.05524832$$

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

$$fx = 0.0541155$$

$$af = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$bw = 500.00$$

$$\text{effective stress from (A.35), } ff,e = 882.7518$$

$$fy = 0.09723711$$

$$af = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff,e = 793.0837$$

$$R = 40.00$$

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

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = 0.05494666$$

$$bo = 440.00$$

$$ho = 190.00$$

bi2 = 459400.00

psh,min = Min(psh,x , psh,y) = 0.00314159

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) = 0.00314159

Ash = Astir*ns = 78.53982

No stirrups, ns = 2.00

bk = 500.00

psh,y (5.4d) = 0.00628319

Ash = Astir*ns = 78.53982

No stirrups, ns = 2.00

bk = 250.00

s = 100.00

fywe = 656.25

fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00294309

c = confinement factor = 1.09431

y1 = 0.0025

sh1 = 0.008

ft1 = 787.50

fy1 = 656.25

su1 = 0.032

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

lo/lou,min = lb/lb = 1.00

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

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

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

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

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 787.50

fy2 = 656.25

su2 = 0.032

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

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

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

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

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

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

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

yv = 0.0025

shv = 0.008

ftv = 787.50

fyv = 656.25

suv = 0.032

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

lo/lou,min = lb/lb = 1.00

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

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

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

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

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

with $f_{sv} = f_s = 656.25$
with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.17529176$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.17529176$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08498995$

and confined core properties:

$b = 440.00$
 $d = 177.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 32.82928$
 $cc (5A.5, TBDY) = 0.00294309$
 $c = \text{confinement factor} = 1.09431$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.23295708$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.23295708$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.11294889$

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

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

--->
 $su (4.9) = 0.23279566$
 $Mu = MRc (4.14) = 1.3221E+008$
 $u = su (4.1) = 0.0002015$

Calculation of ratio l_b/d

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

Calculation of Mu_{2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 0.0002015$
 $Mu = 1.3221E+008$

with full section properties:

$b = 500.00$
 $d = 207.00$
 $d' = 43.00$
 $v = 0.00150304$
 $N = 4666.932$
 $f_c = 30.00$
 $co (5A.5, TBDY) = 0.002$
Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01290198$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $cu = 0.01290198$
 $w_e ((5.4c), TBDY) = ase * sh_{,min} * fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.05524832$
where $f = af * pf * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $fx = 0.0541155$
 $af = 0.45253333$
 $b = 500.00$
 $h = 250.00$
From EC8 A.4.4.3(6), $pf = 2t_f/bw = 0.004064$
 $bw = 500.00$
effective stress from (A.35), $ff_e = 882.7518$

 $fy = 0.09723711$
 $af = 0.45253333$
 $b = 250.00$
 $h = 500.00$
From EC8 A.4.4.3(6), $pf = 2t_f/bw = 0.008128$
 $bw = 250.00$

effective stress from (A.35), $f_{f,e} = 793.0837$

R = 40.00

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se}((5.4d), TBDY) = 0.05494666$

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$

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)

$p_{sh,x} (5.4d) = 0.00314159$

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

No stirrups, $n_s = 2.00$

$b_k = 500.00$

$p_{sh,y} (5.4d) = 0.00628319$

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

No stirrups, $n_s = 2.00$

$b_k = 250.00$

$s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.00294309$

$c = \text{confinement factor} = 1.09431$

$y_1 = 0.0025$

$sh_1 = 0.008$

$ft_1 = 787.50$

$fy_1 = 656.25$

$su_1 = 0.032$

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

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

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

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 $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$fy_2 = 656.25$

$su_2 = 0.032$

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

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

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

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

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

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

with $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$fy_v = 656.25$

$suv = 0.032$

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

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

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

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

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

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

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

with $f_{sv} = f_s = 656.25$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.17529176$

$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.17529176$

$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.08498995$

and confined core properties:

$b = 440.00$

$d = 177.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 32.82928$

$cc (5A.5, TBDY) = 0.00294309$

$c = \text{confinement factor} = 1.09431$

$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.23295708$

$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.23295708$

$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.11294889$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

$s_u (4.9) = 0.23279566$

$M_u = M_{Rc} (4.14) = 1.3221E+008$

$u = s_u (4.1) = 0.0002015$

Calculation of ratio l_b/l_d

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

Calculation of M_{u2}

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

$u = 0.0002015$

$M_u = 1.3221E+008$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00150304$

$N = 4666.932$

$f_c = 30.00$

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

Final value of c_u : $c_u * = \text{shear_factor} * \text{Max}(c_u, cc) = 0.01290198$

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

From (5.4b), TBDY: $c_u = 0.01290198$

$w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$

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

$f_x = 0.0541155$

$a_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A4.4.3(6), $pf = 2tf/bw = 0.004064$
 $bw = 500.00$
effective stress from (A.35), $ff,e = 882.7518$

$fy = 0.09723711$
 $af = 0.45253333$
 $b = 250.00$
 $h = 500.00$
From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$
 $bw = 250.00$
effective stress from (A.35), $ff,e = 793.0837$

$R = 40.00$
Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$
 $fu,f = 1055.00$
 $Ef = 64828.00$
 $u,f = 0.015$
 $ase ((5.4d), TBDY) = 0.05494666$
 $bo = 440.00$
 $ho = 190.00$
 $bi2 = 459400.00$
 $psh,min = Min(psh,x, psh,y) = 0.00314159$

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)

$psh,x (5.4d) = 0.00314159$
 $Ash = Astir*ns = 78.53982$
No stirrups, $ns = 2.00$
 $bk = 500.00$

$psh,y (5.4d) = 0.00628319$
 $Ash = Astir*ns = 78.53982$
No stirrups, $ns = 2.00$
 $bk = 250.00$

$s = 100.00$
 $fywe = 656.25$
 $fce = 30.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00294309$
 $c = \text{confinement factor} = 1.09431$

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

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

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

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

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

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

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

with $fs1 = fs = 656.25$

with $Es1 = Es = 200000.00$

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

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

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

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

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

For calculation of $es_{u2_nominal}$ 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 $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$fy_v = 656.25$

$suv = 0.032$

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

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

$suv = 0.4 \cdot es_{u2_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $es_{u2_nominal} = 0.08$,

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 $fs_v = fs = 656.25$

with $Es_v = Es = 200000.00$

1 = $Asl, \text{ten}/(b \cdot d) \cdot (fs_1/fc) = 0.17529176$

2 = $Asl, \text{com}/(b \cdot d) \cdot (fs_2/fc) = 0.17529176$

v = $Asl, \text{mid}/(b \cdot d) \cdot (fs_v/fc) = 0.08498995$

and confined core properties:

$b = 440.00$

$d = 177.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 32.82928$

$cc (5A.5, TBDY) = 0.00294309$

c = confinement factor = 1.09431

1 = $Asl, \text{ten}/(b \cdot d) \cdot (fs_1/fc) = 0.23295708$

2 = $Asl, \text{com}/(b \cdot d) \cdot (fs_2/fc) = 0.23295708$

v = $Asl, \text{mid}/(b \cdot d) \cdot (fs_v/fc) = 0.11294889$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.23279566$

$Mu = MRc (4.14) = 1.3221E+008$

$u = su (4.1) = 0.0002015$

Calculation of ratio lb/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 405928.36$

Calculation of Shear Strength at edge 1, $V_{r1} = 405928.36$

$V_{r1} = V_{CoI} ((10.3), ASCE 41-17) = knl \cdot V_{CoI0}$

$V_{CoI0} = 405928.36$

$knl = 1$ (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)

$fc' = 30.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$Mu = 4.7466732E-012$

$Vu = 1.0405794E-032$

$d = 0.8 \cdot h = 200.00$
 $Nu = 4666.932$
 $Ag = 125000.00$
From (11.5.4.8), ACI 318-14: $Vs = 164933.614$
 $Av = 157079.633$
 $fy = 525.00$
 $s = 100.00$

Vs is multiplied by $Col = 1.00$
 $s/d = 0.50$

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

$Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, \theta)|)$, 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: $Vs + Vf \leq 363854.192$

$bw = 500.00$

Calculation of Shear Strength at edge 2, $Vr2 = 405928.36$

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

$VCol0 = 405928.36$

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

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

 $= 1$ (normal-weight concrete)

$fc' = 30.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$Mu = 4.7466732E-012$

$Vu = 1.0405794E-032$

$d = 0.8 \cdot h = 200.00$

$Nu = 4666.932$

$Ag = 125000.00$

From (11.5.4.8), ACI 318-14: $Vs = 164933.614$

$Av = 157079.633$

$fy = 525.00$

$s = 100.00$

Vs is multiplied by $Col = 1.00$

$s/d = 0.50$

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

$Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, \theta)|)$, 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: $Vs + Vf \leq 363854.192$

$bw = 500.00$

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, $\gamma = 0.85$
Mean strength values are used for both shear and moment calculations.
Consequently:
New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$
Concrete Elasticity, $E_c = 25742.96$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
New material: Steel Strength, $f_s = 1.25 * f_{sm} = 656.25$

Section Height, $H = 250.00$
Section Width, $W = 500.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.09431
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou, min} > 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = -7.3955710E-032$
EDGE -B-
Shear Force, $V_b = 7.3955710E-032$
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 , $V_e/V_r = 0.47977838$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 240479.187$

with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 3.6072E+008$

$\mu_{1+} = 3.6072E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{1-} = 3.6072E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 3.6072E+008$

$\mu_{2+} = 3.6072E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$\mu_{2-} = 3.6072E+008$, 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:

$\mu = 8.4581924E-005$

$M_u = 3.6072E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00136161$

$N = 4666.932$

$f_c = 30.00$

α (5A.5, TBDY) = 0.002

Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01290198$

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

From (5.4b), TBDY: $\mu_c = 0.01290198$

μ_{cc} ((5.4c), TBDY) = $\alpha \cdot \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$

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

$f_x = 0.0541155$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

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

$b_w = 500.00$

effective stress from (A.35), $f_{fe} = 882.7518$

$f_y = 0.09723711$

$\alpha_f = 0.45253333$

$b = 250.00$

$h = 500.00$

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

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 793.0837$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

α_{se} ((5.4d), TBDY) = 0.05494666

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00314159$$

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)

$$psh,x (5.4d) = 0.00314159$$

$$Ash = Astir*ns = 78.53982$$

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

$$bk = 500.00$$

$$psh,y (5.4d) = 0.00628319$$

$$Ash = Astir*ns = 78.53982$$

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

$$bk = 250.00$$

$$s = 100.00$$

$$fywe = 656.25$$

$$fce = 30.00$$

From ((5.A5), TBDY), TBDY: $cc = 0.00294309$

$$c = \text{confinement factor} = 1.09431$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 787.50$$

$$fy1 = 656.25$$

$$su1 = 0.032$$

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

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

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

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

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

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

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

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

$$y2 = 0.0025$$

$$sh2 = 0.008$$

$$ft2 = 787.50$$

$$fy2 = 656.25$$

$$su2 = 0.032$$

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

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

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

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

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

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

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

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

$$yv = 0.0025$$

$$shv = 0.008$$

$$ftv = 787.50$$

$$fyv = 656.25$$

$$suv = 0.032$$

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

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

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

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

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

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

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

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

with $E_{sv} = E_s = 200000.00$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.15879823$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.15879823$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07699308$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 32.82928$$

$$c_c (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22362502$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.22362502$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.10842425$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

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

--->

$$s_u (4.8) = 0.17214129$$

$$\mu_u = M_{Rc} (4.15) = 3.6072E+008$$

$$u = s_u (4.1) = 8.4581924E-005$$

Calculation of ratio l_b/l_d

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

Calculation of μ_{u1} -

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

$$u = 8.4581924E-005$$

$$\mu_u = 3.6072E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00136161$$

$$N = 4666.932$$

$$f_c = 30.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01290198$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01290198$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$$

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

$$f_x = 0.0541155$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$f_y = 0.09723711$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

bw = 250.00
effective stress from (A.35), $f_{f,e} = 793.0837$

R = 40.00
Effective FRP thickness, $t_f = NL * t * \cos(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $a_{se} ((5.4d), TBDY) = 0.05494666$
 $b_o = 440.00$
 $h_o = 190.00$
 $b_{i2} = 459400.00$

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$
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)

$p_{sh,x} (5.4d) = 0.00314159$
 $A_{sh} = A_{stir} * n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $b_k = 500.00$

$p_{sh,y} (5.4d) = 0.00628319$
 $A_{sh} = A_{stir} * n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $b_k = 250.00$

$s = 100.00$
 $f_{ywe} = 656.25$
 $f_{ce} = 30.00$
From ((5.A5), TBDY), TBDY: $c_c = 0.00294309$
 $c = \text{confinement factor} = 1.09431$

$y_1 = 0.0025$
 $sh_1 = 0.008$
 $ft_1 = 787.50$
 $fy_1 = 656.25$
 $su_1 = 0.032$

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

$l_o/l_{ou,min} = l_b/l_d = 1.00$
 $su_1 = 0.4 * esu1_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,
For calculation of $esu1_{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

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

with $fs_1 = fs = 656.25$
with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$

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

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$
 $su_2 = 0.4 * esu2_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,
For calculation of $esu2_{nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

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

with $fs_2 = fs = 656.25$
with $Es_2 = Es = 200000.00$

$y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $fy_v = 656.25$

suv = 0.032

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

lo/lou,min = lb/d = 1.00

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

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

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

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

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

with fsv = fs = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.15879823

2 = Asl,com/(b*d)*(fs2/fc) = 0.15879823

v = Asl,mid/(b*d)*(fsv/fc) = 0.07699308

and confined core properties:

b = 190.00

d = 427.00

d' = 13.00

fcc (5A.2, TBDY) = 32.82928

cc (5A.5, TBDY) = 0.00294309

c = confinement factor = 1.09431

1 = Asl,ten/(b*d)*(fs1/fc) = 0.22362502

2 = Asl,com/(b*d)*(fs2/fc) = 0.22362502

v = Asl,mid/(b*d)*(fsv/fc) = 0.10842425

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

v < vs,y2 - LHS eq.(4.5) is not satisfied

v < vs,c - RHS eq.(4.5) is satisfied

su (4.8) = 0.17214129

Mu = MRc (4.15) = 3.6072E+008

u = su (4.1) = 8.4581924E-005

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

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

u = 8.4581924E-005

Mu = 3.6072E+008

with full section properties:

b = 250.00

d = 457.00

d' = 43.00

v = 0.00136161

N = 4666.932

fc = 30.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01290198

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

From (5.4b), TBDY: cu = 0.01290198

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.05524832

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

fx = 0.0541155

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), $ff,e = 882.7518$

fy = 0.09723711
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), $ff,e = 793.0837$

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) = 0.05494666
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.00314159
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) = 0.00314159
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00
From ((5.A5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431
y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

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

lo/lou,min = lb/d = 1.00

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

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

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

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

with $fs1 = fs = 656.25$

with $Es1 = Es = 200000.00$

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

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

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

$$s_u = 0.4 * e_{s2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s2_nominal} = 0.08$,

For calculation of $e_{s2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_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.

$$\text{with } f_{s2} = f_s = 656.25$$

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

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$fy_v = 656.25$$

$$s_u = 0.032$$

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

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

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

$$s_u = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } f_{sv} = f_s = 656.25$$

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.15879823$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.15879823$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07699308$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 32.82928$$

$$c_c (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22362502$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.22362502$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.10842425$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

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

--->

$$s_u (4.8) = 0.17214129$$

$$M_u = MR_c (4.15) = 3.6072E+008$$

$$u = s_u (4.1) = 8.4581924E-005$$

Calculation of ratio l_b/l_d

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

Calculation of M_u -

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

$$u = 8.4581924E-005$$

$$M_u = 3.6072E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$d' = 43.00$

$v = 0.00136161$

$N = 4666.932$

$f_c = 30.00$

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

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01290198$

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

From (5.4b), TBDY: $c_u = 0.01290198$

$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$

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

 $f_x = 0.0541155$

$a_f = 0.45253333$

$b = 500.00$

$h = 250.00$

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

$b_w = 500.00$

effective stress from (A.35), $f_{f,e} = 882.7518$

 $f_y = 0.09723711$

$a_f = 0.45253333$

$b = 250.00$

$h = 500.00$

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

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 793.0837$

 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} ((5.4d), TBDY) = 0.05494666$

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$

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)

 $p_{sh,x} (5.4d) = 0.00314159$

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

No stirrups, $n_s = 2.00$

$b_k = 500.00$

 $p_{sh,y} (5.4d) = 0.00628319$

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

No stirrups, $n_s = 2.00$

$b_k = 250.00$

 $s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.00294309$

$c = \text{confinement factor} = 1.09431$

$y_1 = 0.0025$

$sh_1 = 0.008$

$ft_1 = 787.50$

$fy_1 = 656.25$

$su_1 = 0.032$

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

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

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

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

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered

characteristic value $f_{sy1} = f_{s1}/1.2$, from table 5.1, TBDY.

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

with $f_{s1} = f_s = 656.25$

with $E_{s1} = E_s = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$fy_2 = 656.25$

$su_2 = 0.032$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

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

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

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

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered

characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

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

with $f_{s2} = f_s = 656.25$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$fy_v = 656.25$

$su_v = 0.032$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

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

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

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

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

For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

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

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

with $f_{sv} = f_s = 656.25$

with $E_{sv} = E_s = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.15879823$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.15879823$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.07699308$

and confined core properties:

$b = 190.00$

$d = 427.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 32.82928$

$cc (5A.5, TBDY) = 0.00294309$

c = confinement factor = 1.09431

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.22362502$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.22362502$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.10842425$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

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

---->

$su (4.8) = 0.17214129$

$Mu = MRc (4.15) = 3.6072E+008$

u = $su (4.1) = 8.4581924E-005$

Calculation of ratio l_b/l_d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 501229.73$

Calculation of Shear Strength at edge 1, $V_{r1} = 501229.73$

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

$V_{Col0} = 501229.73$

$k_{nl} = 1$ (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).

 $k = 1$ (normal-weight concrete)

$f_c' = 30.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 5.0983467E-013$

$\nu_u = 7.3955710E-032$

$d = 0.8 * h = 400.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 329867.229$

$A_v = 157079.633$

$f_y = 525.00$

$s = 100.00$

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

$s/d = 0.25$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 240803.347$

$f = 0.95$, 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: $\theta = b1 + 90^\circ = 90.00$

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

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

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 363854.192$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 501229.73$

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

$V_{Col0} = 501229.73$

$k_{nl} = 1$ (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).

 $k = 1$ (normal-weight concrete)

$f_c' = 30.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 5.0983467E-013$

$\nu_u = 7.3955710E-032$

$d = 0.8 * h = 400.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 329867.229$

$A_v = 157079.633$

$f_y = 525.00$

$s = 100.00$

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

$s/d = 0.25$

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

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

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

Vf = Min(|Vf(45, 1)|, |Vf(-45, a1)|), with:

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

dfv = d (figure 11.2, ACI 440) = 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 <= 363854.192

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: (a)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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

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

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 25742.96$

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

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/l_d >= 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, t = 1.016

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, Ef = 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

Bending Moment, M = 4.8412113E-010

Shear Force, V2 = -3769.985

Shear Force, $V_3 = -1.2662512E-013$
Axial Force, $F = -4665.423$
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: $A_{s,ten} = 829.3805$
-Compression: $A_{s,com} = 829.3805$
-Middle: $A_{s,mid} = 402.1239$
Mean Diameter of Tension Reinforcement, $DbL = 18.66667$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = 1.0^*$ $u = 0.01423028$
 $u = y + p = 0.01423028$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00923028$ ((4.29), Biskinis Phd)
 $M_y = 9.2818E+007$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 5.0279E+012$
factor = 0.30
 $A_g = 125000.00$
 $f_c' = 30.00$
 $N = 4665.423$
 $E_c * I_g = 1.6760E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 1.8256818E-005$
with $f_y = 525.00$
 $d = 207.00$
 $y = 0.30540146$
 $A = 0.01999779$
 $B = 0.01210997$
with $pt = 0.00801334$
 $pc = 0.00801334$
 $p_v = 0.00388525$
 $N = 4665.423$
 $b = 500.00$
 $" = 0.20772947$
 $y_{comp} = 3.3724871E-005$
with f_c^* (12.3, (ACI 440)) = 30.44529
 $f_c = 30.00$
 $f_l = 0.9425867$
 $b = 500.00$
 $h = 250.00$
 $A_g = 125000.00$
From (12.9), ACI 440: $k_a = 0.1506892$
 $g = pt + pc + p_v = 0.01991193$
 $rc = 40.00$
 $A_e / A_c = 0.60275679$
Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 25742.96$
 $y = 0.30493935$
 $A = 0.01980606$

B = 0.01202411
with Es = 200000.00

Calculation of ratio l_b/l_d

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

- Calculation of ρ -

From table 10-8: $\rho = 0.005$

with:

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

shear control ratio $V_y E / V_{CoI} E = 0.21712381$

$d = 207.00$

$s = 0.00$

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

$A_v = 157.0796$, 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.

$N_{UD} = 4665.423$

$A_g = 125000.00$

$f_{cE} = 30.00$

$f_{ytE} = f_{ylE} = 0.00$

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

$b = 500.00$

$d = 207.00$

$f_{cE} = 30.00$

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

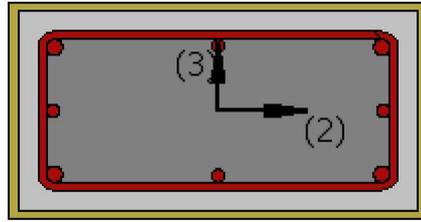
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

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, $\gamma = 0.85$

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

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

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 20.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 420.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

#####

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

New material: Concrete Strength, $f_c = f_{cm} = 30.00$

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = 4.8412113E-010$

Shear Force, $V_a = -1.2662512E-013$

EDGE -B-

Bending Moment, $M_b = -1.0374225E-010$

Shear Force, $V_b = 1.2662512E-013$
 BOTH EDGES
 Axial Force, $F = -4665.423$
 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, $Db_{L,ten} = 18.66667$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0 \cdot V_n = 347902.448$
 V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{Col} = 347902.448$
 $V_{Col} = 347902.448$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.00$

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' 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)
 $M/Vd = 2.00$
 $M_u = 4.8412113E-010$
 $V_u = 1.2662512E-013$
 $d = 0.8 \cdot h = 200.00$
 $N_u = 4665.423$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 131946.891$
 $A_v = 157079.633$
 $f_y = 420.00$
 $s = 100.00$

V_s is multiplied by $\phi_{Col} = 1.00$
 $s/d = 0.50$

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

$V_f = \text{Min}(|V_f(45^\circ, \alpha_1)|, |V_f(-45^\circ, \alpha_1)|)$, 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: $V_s + V_f \leq 297085.704$

$b_w = 500.00$

$displacement_ductility_demand$ is calculated as ϕ / y

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

From analysis, chord rotation $\theta = 3.6013121E-020$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00923028$ ((4.29), Biskinis Phd)

$M_y = 9.2818E+007$

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

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 5.0279E+012$

factor = 0.30

$A_g = 125000.00$

$f_c' = 30.00$

$N = 4665.423$

$E_c * I_g = 1.6760E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$y_{ten} = 1.8256818E-005$

with $f_y = 525.00$

$d = 207.00$

$y = 0.30540146$

$A = 0.01999779$

$B = 0.01210997$

with $pt = 0.00801334$

$pc = 0.00801334$

$pv = 0.00388525$

$N = 4665.423$

$b = 500.00$

" = 0.20772947

$y_{comp} = 3.3724871E-005$

with f_c^* (12.3, (ACI 440)) = 30.44529

$f_c = 30.00$

$fl = 0.9425867$

$b = 500.00$

$h = 250.00$

$A_g = 125000.00$

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

$g = pt + pc + pv = 0.01991193$

$rc = 40.00$

$A_e/A_c = 0.60275679$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 25742.96$

$y = 0.30493935$

$A = 0.01980606$

$B = 0.01202411$

with $E_s = 200000.00$

Calculation of ratio I_b/I_d

Adequate Lap Length: $I_b/I_d \geq 1$

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

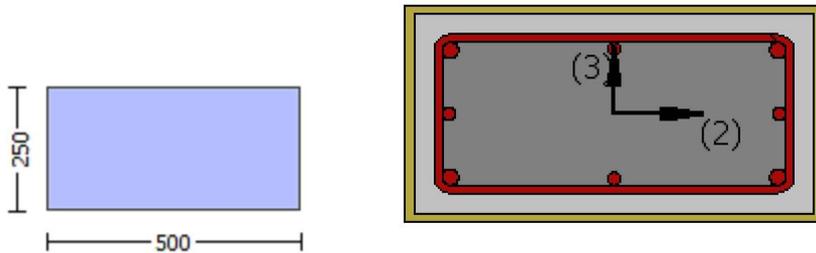
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_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, $\gamma = 0.85$

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

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.09431

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou, \min} \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $bi = 0.00^\circ$

Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, Va = -1.0405794E-032
EDGE -B-
Shear Force, Vb = 1.0405794E-032
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 , $V_e/V_r = 0.21712381$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 88136.71$
with
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 1.3221E+008$
 $\mu_{1+} = 1.3221E+008$, 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
 $\mu_{1-} = 1.3221E+008$, 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
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 1.3221E+008$
 $\mu_{2+} = 1.3221E+008$, 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
 $\mu_{2-} = 1.3221E+008$, 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:
 $\mu = 0.0002015$
 $M_u = 1.3221E+008$

with full section properties:

$b = 500.00$
 $d = 207.00$
 $d' = 43.00$
 $v = 0.00150304$
 $N = 4666.932$
 $f_c = 30.00$
 $\alpha (5A.5, TBDY) = 0.002$
Final value of μ_c : $\mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01290198$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\mu_c = 0.01290198$
 $\mu_{ve} ((5.4c), TBDY) = \alpha s_e^* s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$
where $f = \alpha f_p^* f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.0541155$
 $\alpha f = 0.45253333$
 $b = 500.00$
 $h = 250.00$
From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.004064$

bw = 500.00
effective stress from (A.35), $f_{f,e} = 882.7518$

fy = 0.09723711
af = 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), $f_{f,e} = 793.0837$

R = 40.00
Effective FRP thickness, $t_f = NL*t*Cos(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.05494666
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.00314159

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) = 0.00314159
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431

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

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

lo/lou,min = lb/ld = 1.00

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

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

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value $f_{s1} = f_s/1.2$, 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 $f_{s1} = f_s = 656.25$

with $E_{s1} = E_s = 200000.00$

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

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

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

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

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

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

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

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

with $f_{s2} = f_s = 656.25$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$f_{yv} = 656.25$

$s_{uv} = 0.032$

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

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

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

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

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

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

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

with $f_{sv} = f_s = 656.25$

with $E_{sv} = E_s = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.17529176$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.17529176$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08498995$

and confined core properties:

b = 440.00

d = 177.00

d' = 13.00

f_{cc} (5A.2, TBDY) = 32.82928

cc (5A.5, TBDY) = 0.00294309

c = confinement factor = 1.09431

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.23295708$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.23295708$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.11294889$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.23279566

Mu = MRc (4.14) = 1.3221E+008

u = su (4.1) = 0.0002015

Calculation of ratio l_b/d

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

Calculation of Mu1-

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

u = 0.0002015

Mu = 1.3221E+008

with full section properties:

b = 500.00

d = 207.00

d' = 43.00

v = 0.00150304

N = 4666.932

f_c = 30.00

co (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} \cdot \text{Max}(\phi_u, \phi_c) = 0.01290198$

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

From (5.4b), TBDY: $c_u = 0.01290198$

w_e ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$

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

 $f_x = 0.0541155$

$af = 0.45253333$

$b = 500.00$

$h = 250.00$

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

$bw = 500.00$

effective stress from (A.35), $ff_e = 882.7518$

 $f_y = 0.09723711$

$af = 0.45253333$

$b = 250.00$

$h = 500.00$

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

$bw = 250.00$

effective stress from (A.35), $ff_e = 793.0837$

 $R = 40.00$

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) = 0.05494666

$bo = 440.00$

$ho = 190.00$

$bi2 = 459400.00$

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00314159$

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) = 0.00314159

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

No stirrups, $n_s = 2.00$

$bk = 500.00$

 psh_y (5.4d) = 0.00628319

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

No stirrups, $n_s = 2.00$

$bk = 250.00$

 $s = 100.00$

$fy_{we} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00294309$

$c =$ confinement factor = 1.09431

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 787.50$

$fy1 = 656.25$

$su1 = 0.032$

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

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

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

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

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

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

with $fs1 = fs = 656.25$

with $Es1 = Es = 200000.00$

$y2 = 0.0025$

$sh2 = 0.008$

$$f_{t2} = 787.50$$

$$f_{y2} = 656.25$$

$$s_{u2} = 0.032$$

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

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

$$s_{u2} = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su2,nominal} = 0.08$,

For calculation of $e_{su2,nominal}$ and $y_2, sh_2, f_{t2}, f_{y2}$, it is considered
characteristic value $f_{s2} = f_{s2}/1.2$, from table 5.1, TBDY.

$y_1, sh_1, f_{t1}, f_{y1}$, are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s2} = f_s = 656.25$$

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

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$f_{tv} = 787.50$$

$$f_{yv} = 656.25$$

$$s_{uv} = 0.032$$

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

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

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

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

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

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

$y_1, sh_1, f_{t1}, f_{y1}$, are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{sv} = f_s = 656.25$$

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.17529176$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.17529176$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.08498995$$

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 32.82928$$

$$cc (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.23295708$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.23295708$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.11294889$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

$$s_u (4.9) = 0.23279566$$

$$M_u = M_{Rc} (4.14) = 1.3221E+008$$

$$u = s_u (4.1) = 0.0002015$$

Calculation of ratio l_b/l_d

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

Calculation of M_{u2+}

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

$$u = 0.0002015$$

$$M_u = 1.3221E+008$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00150304$$

$$N = 4666.932$$

$$f_c = 30.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01290198$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01290198$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$$

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

$$f_x = 0.0541155$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$f_y = 0.09723711$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 793.0837$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.00314159$$

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

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

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00628319$$

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

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

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 30.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$y_1 = 0.0025$$

$$s_{h1} = 0.008$$

$$f_{t1} = 787.50$$

$$f_{y1} = 656.25$$

$$s_{u1} = 0.032$$

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

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

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

From table 5A.1, TBDY: $e_{s1_nominal} = 0.08$,

For calculation of $e_{s1_nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $f_{sy1} = f_s/1.2$, 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.

$$\text{with } f_{s1} = f_s = 656.25$$

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

$$y_2 = 0.0025$$

$$sh_2 = 0.008$$

$$ft_2 = 787.50$$

$$fy_2 = 656.25$$

$$s_u2 = 0.032$$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

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

$$s_u2 = 0.4 * e_{s2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s2_nominal} = 0.08$,

For calculation of $e_{s2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $f_{sy2} = f_s/1.2$, 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.

$$\text{with } f_{s2} = f_s = 656.25$$

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

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$fy_v = 656.25$$

$$s_{u,v} = 0.032$$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

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

$$s_{u,v} = 0.4 * e_{s_{u,v}_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s_{u,v}_nominal} = 0.08$,

considering characteristic value $f_{s_{y,v}} = f_{sv}/1.2$, 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 $f_{s_{y,v}} = f_{sv}/1.2$, 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.

$$\text{with } f_{sv} = f_s = 656.25$$

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.17529176$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.17529176$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.08498995$$

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 32.82928$$

$$cc (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.23295708$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.23295708$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.11294889$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.23279566$$

$$\mu = M_{Rc} (4.14) = 1.3221E+008$$

$$u = s_u (4.1) = 0.0002015$$

Calculation of ratio l_b/l_d

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

Calculation of Mu2-

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

$$\mu = 0.0002015$$

$$Mu = 1.3221E+008$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00150304$$

$$N = 4666.932$$

$$f_c = 30.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_o) = 0.01290198$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01290198$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$$

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

$$f_x = 0.0541155$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$f_y = 0.09723711$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 793.0837$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.00314159$$

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

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

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00628319$$

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

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

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 30.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00294309$
 $c = \text{confinement factor} = 1.09431$

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

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

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

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

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

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

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

with $fs1 = fs = 656.25$

with $Es1 = Es = 200000.00$

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

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

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

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

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

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

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

with $fs2 = fs = 656.25$

with $Es2 = Es = 200000.00$

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

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

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

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

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

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

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

with $fsv = fs = 656.25$

with $Esv = Es = 200000.00$

$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.17529176$

$2 = Asl,com / (b * d) * (fs2 / fc) = 0.17529176$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.08498995$

and confined core properties:

$b = 440.00$

$d = 177.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 32.82928$

$cc (5A.5, TBDY) = 0.00294309$

$c = \text{confinement factor} = 1.09431$

$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.23295708$

$2 = Asl,com / (b * d) * (fs2 / fc) = 0.23295708$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.11294889$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_s$, y_2 - LHS eq.(4.5) is satisfied

--->

$$\mu_u(4.9) = 0.23279566$$

$$\mu_u = M_{Rc}(4.14) = 1.3221E+008$$

$$u = \mu_u(4.1) = 0.0002015$$

Calculation of ratio l_b/l_d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 405928.36$

Calculation of Shear Strength at edge 1, $V_{r1} = 405928.36$

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

$$V_{Col0} = 405928.36$$

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

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).

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

$$f_c' = 30.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$\mu_u = 4.7466732E-012$$

$$V_u = 1.0405794E-032$$

$$d = 0.8 * h = 200.00$$

$$N_u = 4666.932$$

$$A_g = 125000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 164933.614$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

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

$$s/d = 0.50$$

$$V_f((11-3)-(11.4), ACI 440) = 109072.851$$

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

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

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

This later relation, considered as a function $V_f(\theta, a_i)$, 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.

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

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

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

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

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 363854.192$$

$$b_w = 500.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 405928.36$

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

$$V_{Col0} = 405928.36$$

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

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).

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

$$f_c' = 30.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$M/Vd = 2.00$
 $\mu_u = 4.7466732E-012$
 $\mu_v = 1.0405794E-032$
 $d = 0.8 \cdot h = 200.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 164933.614$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.50$
 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) $\sin + \cos$ is replaced with $(\cot + \cot_a)\sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (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: $V_s + V_f \leq 363854.192$
 $b_w = 500.00$

 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, $\lambda = 0.85$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$
 Concrete Elasticity, $E_c = 25742.96$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 656.25$
 #####
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.09431
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{ou, \min} \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = -7.3955710E-032$

EDGE -B-

Shear Force, $V_b = 7.3955710E-032$

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, $V_e/V_r = 0.47977838$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 240479.187$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 3.6072E+008$

$M_{u1+} = 3.6072E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 3.6072E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 3.6072E+008$

$M_{u2+} = 3.6072E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 3.6072E+008$, 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:

$\phi_u = 8.4581924E-005$

$M_u = 3.6072E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00136161$

$N = 4666.932$

$f_c = 30.00$

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

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01290198$

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

From (5.4b), TBDY: $c_u = 0.01290198$

w_e ((5.4c), TBDY) = $ase * sh_{min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$

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

 $f_x = 0.0541155$

$af = 0.45253333$

$b = 500.00$

$h = 250.00$

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

$bw = 500.00$

effective stress from (A.35), $ff_e = 882.7518$

 $f_y = 0.09723711$

$af = 0.45253333$

$b = 250.00$

$h = 500.00$

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

$bw = 250.00$

effective stress from (A.35), $ff_e = 793.0837$

 $R = 40.00$

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) = 0.05494666

$b_o = 440.00$

$h_o = 190.00$

$bi_2 = 459400.00$

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00314159$

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) = 0.00314159

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

No stirrups, $n_s = 2.00$

$b_k = 500.00$

 psh_y (5.4d) = 0.00628319

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

No stirrups, $n_s = 2.00$

$b_k = 250.00$

 $s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00294309$

$c =$ confinement factor = 1.09431

$y_1 = 0.0025$

$sh_1 = 0.008$

$ft_1 = 787.50$

$fy_1 = 656.25$

$su_1 = 0.032$

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

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

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

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

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

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

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$$f_y2 = 656.25$$

$$s_u2 = 0.032$$

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

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

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

From table 5A.1, TBDY: $e_{su2,nominal} = 0.08$,

For calculation of $e_{su2,nominal}$ and y_2, sh_2, ft_2, f_y2 , it is considered
characteristic value $f_{sy2} = f_s2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, f_y1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s2} = f_s = 656.25$$

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

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$f_{y_v} = 656.25$$

$$s_{u_v} = 0.032$$

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

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

$$s_{u_v} = 0.4 * e_{su_v,nominal} ((5.5), TBDY) = 0.032$$

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

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

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

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

$$\text{with } f_{sv} = f_s = 656.25$$

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.15879823$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.15879823$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.07699308$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 32.82928$$

$$cc (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.22362502$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.22362502$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.10842425$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

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

--->

$$s_u (4.8) = 0.17214129$$

$$\mu_u = M_{Rc} (4.15) = 3.6072E+008$$

$$u = s_u (4.1) = 8.4581924E-005$$

Calculation of ratio l_b/l_d

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

Calculation of μ_{u1} -

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

$$u = 8.4581924E-005$$

Mu = 3.6072E+008

with full section properties:

b = 250.00

d = 457.00

d' = 43.00

v = 0.00136161

N = 4666.932

fc = 30.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01290198

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

From (5.4b), TBDY: cu = 0.01290198

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+ Min(fx, fy) = 0.05524832

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

fx = 0.0541155

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), ffe = 882.7518

fy = 0.09723711

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), ffe = 793.0837

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) = 0.05494666

bo = 440.00

ho = 190.00

bi2 = 459400.00

psh,min = Min(psh,x , psh,y) = 0.00314159

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) = 0.00314159

Ash = Astir*ns = 78.53982

No stirups, ns = 2.00

bk = 500.00

psh,y (5.4d) = 0.00628319

Ash = Astir*ns = 78.53982

No stirups, ns = 2.00

bk = 250.00

s = 100.00

fywe = 656.25

fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00294309

c = confinement factor = 1.09431

y1 = 0.0025

sh1 = 0.008

ft1 = 787.50

fy1 = 656.25

su1 = 0.032

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

Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

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

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

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

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

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 787.50

fy2 = 656.25

su2 = 0.032

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

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

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

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

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

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

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

yv = 0.0025

shv = 0.008

ftv = 787.50

fyv = 656.25

suv = 0.032

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

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

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

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

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

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

with fsv = fs = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.15879823

2 = Asl,com/(b*d)*(fs2/fc) = 0.15879823

v = Asl,mid/(b*d)*(fsv/fc) = 0.07699308

and confined core properties:

b = 190.00

d = 427.00

d' = 13.00

fcc (5A.2, TBDY) = 32.82928

cc (5A.5, TBDY) = 0.00294309

c = confinement factor = 1.09431

1 = Asl,ten/(b*d)*(fs1/fc) = 0.22362502

2 = Asl,com/(b*d)*(fs2/fc) = 0.22362502

v = Asl,mid/(b*d)*(fsv/fc) = 0.10842425

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is not satisfied

--->

v < vs,c - RHS eq.(4.5) is satisfied

--->

su (4.8) = 0.17214129

Mu = MRc (4.15) = 3.6072E+008

u = su (4.1) = 8.4581924E-005

Calculation of ratio l_b/d

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

Calculation of μ_{2+}

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

$$\mu = 8.4581924E-005$$

$$\mu_{2+} = 3.6072E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00136161$$

$$N = 4666.932$$

$$f_c = 30.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01290198$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01290198$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * \text{sh}_{, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$$

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

$$f_x = 0.0541155$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$f_y = 0.09723711$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 793.0837$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh, \min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.00314159$$

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

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

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00628319$$

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

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

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{yve} = 656.25$$

$$f_{ce} = 30.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00294309$

$$c = \text{confinement factor} = 1.09431$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$$fy_1 = 656.25$$

$$su_1 = 0.032$$

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

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

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

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

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

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

$$\text{with } fs_1 = fs = 656.25$$

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

$$y_2 = 0.0025$$

$$sh_2 = 0.008$$

$$ft_2 = 787.50$$

$$fy_2 = 656.25$$

$$su_2 = 0.032$$

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

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

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

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

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

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

$$\text{with } fs_2 = fs = 656.25$$

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

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$fy_v = 656.25$$

$$suv = 0.032$$

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

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

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

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

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

For calculation of $esuv_{\text{nominal}}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsyv = fsv/1.2$, 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.

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

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

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.15879823$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.15879823$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.07699308$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, \text{TBDY}) = 32.82928$$

$$cc (5A.5, \text{TBDY}) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.22362502$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.22362502$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.10842425$$

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

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

s_u (4.8) = 0.17214129
 $M_u = M_{Rc}$ (4.15) = 3.6072E+008
 $u = s_u$ (4.1) = 8.4581924E-005

Calculation of ratio l_b/l_d

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

Calculation of M_{u2} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 8.4581924E-005$
 $M_u = 3.6072E+008$

with full section properties:

$b = 250.00$
 $d = 457.00$
 $d' = 43.00$
 $v = 0.00136161$
 $N = 4666.932$
 $f_c = 30.00$
 α (5A.5, TBDY) = 0.002

Final value of α : $\alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01290198$

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

From (5.4b), TBDY: $\alpha = 0.01290198$

w_e ((5.4c), TBDY) = $\alpha s_e * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$

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

 $f_x = 0.0541155$
 $\alpha_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.004064$
 $b_w = 500.00$
effective stress from (A.35), $f_{f,e} = 882.7518$

 $f_y = 0.09723711$
 $\alpha_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$
 $b_w = 250.00$
effective stress from (A.35), $f_{f,e} = 793.0837$

 $R = 40.00$
Effective FRP thickness, $t_f = N L^* t \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{f,e} = 0.015$
 α_s ((5.4d), TBDY) = 0.05494666
 $b_o = 440.00$
 $h_o = 190.00$
 $b_i^2 = 459400.00$

$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$

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) = 0.00314159
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431

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

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

lo/lou,min = lb/d = 1.00

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

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

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

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

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

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

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

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

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

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

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

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

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

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

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

lo/lou,min = lb/d = 1.00

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

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

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

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

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

with fsv = fs = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.15879823

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.15879823$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07699308$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 32.82928$$

$$c_c (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22362502$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.22362502$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.10842425$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

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

--->

$$s_u (4.8) = 0.17214129$$

$$M_u = M_{Rc} (4.15) = 3.6072E+008$$

$$u = s_u (4.1) = 8.4581924E-005$$

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 501229.73$

Calculation of Shear Strength at edge 1, $V_{r1} = 501229.73$

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

$$V_{Col0} = 501229.73$$

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

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).

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

$$f_c' = 30.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$M_u = 5.0983467E-013$$

$$V_u = 7.3955710E-032$$

$$d = 0.8 * h = 400.00$$

$$N_u = 4666.932$$

$$A_g = 125000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 329867.229$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

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

$$s/d = 0.25$$

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

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

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

In (11.3) $\sin \theta + \cos \theta$ 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.

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

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

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

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

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

$E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 363854.192$
 $bw = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 501229.73$
 $V_{r2} = V_{CoI} ((10.3), ASCE 41-17) = knl * V_{CoIO}$
 $V_{CoIO} = 501229.73$
 $knl = 1$ (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)
 $f_c' = 30.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 5.0983467E-013$
 $V_u = 7.3955710E-032$
 $d = 0.8 * h = 400.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 329867.229$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$

V_s is multiplied by $Col = 1.00$
 $s/d = 0.25$

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

$f = 0.95$, 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 θ is the angle of the crack direction (see KANEPE).

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

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

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

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

$d_{fv} = d$ (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: $V_s + V_f \leq 363854.192$
 $bw = 250.00$

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, $\gamma = 0.85$

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

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

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 25742.96$
Steel Elasticity, $E_s = 200000.00$
Section Height, $H = 250.00$
Section Width, $W = 500.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_b/d >= 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -1.1312E+007$
Shear Force, $V_2 = -3769.985$
Shear Force, $V_3 = -1.2662512E-013$
Axial Force, $F = -4665.423$
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, $Db_L = 18.66667$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = 1.0^*$ $u = 0.0152687$
 $u = y + p = 0.0152687$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.01029579$ ((4.29), Biskinis Phd)
 $M_y = 2.0703E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3000.571
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 2.0112E+013$
factor = 0.30
 $A_g = 125000.00$
 $f_c' = 30.00$
 $N = 4665.423$
 $E_c * I_g = 6.7039E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 7.9424740E-006$

with $f_y = 525.00$
 $d = 457.00$
 $y = 0.27680185$
 $A = 0.01811616$
 $B = 0.0099456$
 with $p_t = 0.00725935$
 $p_c = 0.00725935$
 $p_v = 0.00351968$
 $N = 4665.423$
 $b = 250.00$
 $\theta = 0.0940919$
 $y_{comp} = 1.6862746E-005$
 with $f_c^* (12.3, (ACI 440)) = 30.44585$
 $f_c = 30.00$
 $f_l = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $A_g = 125000.00$
 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, $t_f = N L^* t^* \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 25742.96$
 $y = 0.27624702$
 $A = 0.01794247$
 $B = 0.00986782$
 with $E_s = 200000.00$

 Calculation of ratio l_b/d

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

 - Calculation of p -

 From table 10-8: $p = 0.00497291$

with:

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

shear control ratio $V_y E/V_{CoI} E = 0.47977838$

$d = 457.00$

$s = 0.00$

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

$A_v = 157.0796$, 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.

$N U D = 4665.423$

$A_g = 125000.00$

$f_c E = 30.00$

$f_y t E = f_y l E = 0.00$

$p_l = \text{Area_Tot_Long_Rein} / (b^* d) = 0.01803838$

$b = 250.00$

$d = 457.00$

$f_c E = 30.00$

 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

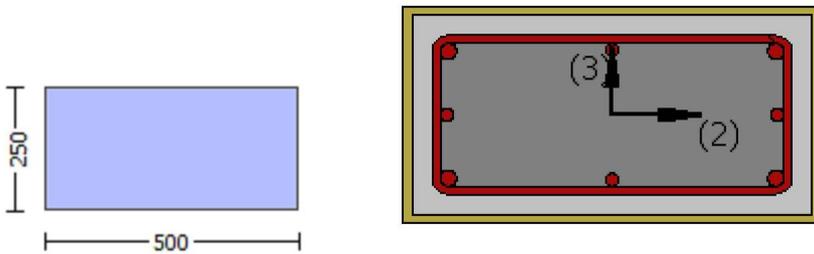
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

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, $\gamma = 0.85$

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

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

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 20.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 420.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

#####

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

New material: Concrete Strength, $f_c = f_{cm} = 30.00$

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

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

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -1.1312E+007$
Shear Force, $V_a = -3769.985$
EDGE -B-
Bending Moment, $M_b = -0.00064216$
Shear Force, $V_b = 3769.985$
BOTH EDGES
Axial Force, $F = -4665.423$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_{lt} = 0.00$
-Compression: $As_{lc} = 2060.885$
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, $Db_{L,ten} = 18.66667$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0 \cdot V_n = 409422.053$
 $V_n ((10.3), ASCE 41-17) = knl \cdot V_{Col} = 409422.053$
 $V_{Col} = 409422.053$
 $knl = 1.00$
 $displacement_ductility_demand = 0.0819531$

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)
 $fc' = 20.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 0.00064216$
 $V_u = 3769.985$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4665.423$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 263893.783$
 $A_v = 157079.633$
 $f_y = 420.00$
 $s = 100.00$
 V_s is multiplied by $Col = 1.00$
 $s/d = 0.25$
 $V_f ((11-3)-(11.4), ACI 440) = 240803.347$
 $f = 0.95$, 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 $V_f(\theta)$, is implemented for every different fiber orientation θ , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

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

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

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

$d_{fv} = d$ (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: $V_s + V_f \leq 297085.704$

$b_w = 250.00$

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 $\theta = 8.4361113E-005$

$y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00102938$ ((4.29), Biskinis Phd)

$M_y = 2.0703E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00

From table 10.5, ASCE 41_17: $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 2.0112E+013$

factor = 0.30

$A_g = 125000.00$

$f_c' = 30.00$

$N = 4665.423$

$E_c \cdot I_g = 6.7039E+013$

Calculation of Yielding Moment M_y

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

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

$y_{\text{ten}} = 7.9424740E-006$

with $f_y = 525.00$

$d = 457.00$

$y = 0.27680185$

$A = 0.01811616$

$B = 0.0099456$

with $p_t = 0.00725935$

$p_c = 0.00725935$

$p_v = 0.00351968$

$N = 4665.423$

$b = 250.00$

$\alpha = 0.0940919$

$y_{\text{comp}} = 1.6862746E-005$

with f_c^* (12.3, (ACI 440)) = 30.44585

$f_c = 30.00$

$f_l = 0.9425867$

$b = 250.00$

$h = 500.00$

$A_g = 125000.00$

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, $t_f = NL \cdot t \cdot \cos(\theta) = 1.016$

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 25742.96$

$y = 0.27624702$

A = 0.01794247
B = 0.00986782
with Es = 200000.00

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

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

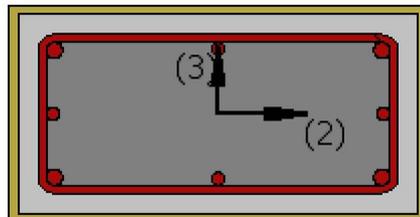
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (u)

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, = 0.85

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

Consequently:

New material of Secondary Member: Concrete Strength, fc = fcm = 30.00

New material of Secondary Member: Steel Strength, fs = fsm = 525.00

Concrete Elasticity, Ec = 25742.96

Steel Elasticity, Es = 200000.00

#####

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

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.09431

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou}, \min \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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

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, $V_a = -1.0405794E-032$

EDGE -B-

Shear Force, $V_b = 1.0405794E-032$

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, $V_e/V_r = 0.21712381$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 88136.71$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.3221E+008$

$M_{u1+} = 1.3221E+008$, 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

$M_{u1-} = 1.3221E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.3221E+008$

$M_{u2+} = 1.3221E+008$, 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

$M_{u2-} = 1.3221E+008$, 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:

$$u = 0.0002015$$

$$Mu = 1.3221E+008$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00150304$$

$$N = 4666.932$$

$$f_c = 30.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01290198$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.01290198$$

$$\omega_e (5.4c, TBDY) = a_{se} * \frac{\text{sh}_{\min} * f_{ywe}}{f_{ce}} + \text{Min}(\phi_x, \phi_y) = 0.05524832$$

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

$$\phi_x = 0.0541155$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$\phi_y = 0.09723711$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 793.0837$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$\text{psh}_{\min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.00314159$$

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

$$\text{psh}_x (5.4d) = 0.00314159$$

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

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

$$b_k = 500.00$$

$$\text{psh}_y (5.4d) = 0.00628319$$

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

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

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 30.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$f_{t1} = 787.50$$

$$f_{y1} = 656.25$$

su1 = 0.032

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

lo/lou,min = lb/d = 1.00

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

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

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

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

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 787.50

fy2 = 656.25

su2 = 0.032

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

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

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

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

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

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

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

yv = 0.0025

shv = 0.008

ftv = 787.50

fyv = 656.25

suv = 0.032

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

lo/lou,min = lb/d = 1.00

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

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

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

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

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

with fsv = fs = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17529176

2 = Asl,com/(b*d)*(fs2/fc) = 0.17529176

v = Asl,mid/(b*d)*(fsv/fc) = 0.08498995

and confined core properties:

b = 440.00

d = 177.00

d' = 13.00

fcc (5A.2, TBDY) = 32.82928

cc (5A.5, TBDY) = 0.00294309

c = confinement factor = 1.09431

1 = Asl,ten/(b*d)*(fs1/fc) = 0.23295708

2 = Asl,com/(b*d)*(fs2/fc) = 0.23295708

v = Asl,mid/(b*d)*(fsv/fc) = 0.11294889

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

su (4.9) = 0.23279566

Mu = MRc (4.14) = 1.3221E+008

u = su (4.1) = 0.0002015

Calculation of ratio l_b/d

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

Calculation of μ_1

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

$\mu_u = 0.0002015$

$\mu_1 = 1.3221E+008$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00150304$

$N = 4666.932$

$f_c = 30.00$

α_{co} (5A.5, TBDY) = 0.002

Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.01290198$

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

From (5.4b), TBDY: $\mu_u = 0.01290198$

μ_{we} ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$

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

$f_x = 0.0541155$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

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

$b_w = 500.00$

effective stress from (A.35), $f_{fe} = 882.7518$

$f_y = 0.09723711$

$\alpha_f = 0.45253333$

$b = 250.00$

$h = 500.00$

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

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 793.0837$

$R = 40.00$

Effective FRP thickness, $t_f = N L * t * \text{Cos}(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{u,f} = 0.015$

α_{se} ((5.4d), TBDY) = 0.05494666

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$

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) = 0.00314159

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

No stirrups, $n_s = 2.00$

$b_k = 500.00$

$p_{sh,y}$ (5.4d) = 0.00628319

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

No stirrups, $n_s = 2.00$

$b_k = 250.00$

$$s = 100.00$$

$$fy_{we} = 656.25$$

$$f_{ce} = 30.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00294309$

$$c = \text{confinement factor} = 1.09431$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$$fy_1 = 656.25$$

$$su_1 = 0.032$$

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

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

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

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

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

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

$$\text{with } fs_1 = fs = 656.25$$

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

$$y_2 = 0.0025$$

$$sh_2 = 0.008$$

$$ft_2 = 787.50$$

$$fy_2 = 656.25$$

$$su_2 = 0.032$$

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

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

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

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

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

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

$$\text{with } fs_2 = fs = 656.25$$

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

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$fy_v = 656.25$$

$$suv = 0.032$$

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

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

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

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

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

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

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

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

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

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.17529176$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.17529176$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.08498995$$

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$fcc (5A.2, \text{TBDY}) = 32.82928$$

$$cc (5A.5, \text{TBDY}) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.23295708$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.23295708$$

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.11294889$$

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

--->

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

--->

$$s_u(4.9) = 0.23279566$$

$$M_u = M_{Rc}(4.14) = 1.3221E+008$$

$$u = s_u(4.1) = 0.0002015$$

Calculation of ratio l_b/l_d

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

Calculation of M_{u2+}

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

$$u = 0.0002015$$

$$M_u = 1.3221E+008$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00150304$$

$$N = 4666.932$$

$$f_c = 30.00$$

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

$$\text{Final value of } \alpha: \alpha^* = \text{shear_factor} \cdot \text{Max}(\alpha, \alpha_c) = 0.01290198$$

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

$$\text{From (5.4b), TBDY: } \alpha_c = 0.01290198$$

$$\alpha_{we}((5.4c), TBDY) = \alpha_{se} \cdot \text{sh}_{, \min} \cdot f_{ywe} / f_{ce} + \text{Min}(\alpha_x, \alpha_y) = 0.05524832$$

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

$$\alpha_x = 0.0541155$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 882.7518$$

$$\alpha_y = 0.09723711$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 793.0837$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(\beta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se}((5.4d), TBDY) = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh, \min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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) = 0.00314159
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431

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

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

lo/lou,min = lb/d = 1.00

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

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

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

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

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

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

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

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

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

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

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

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

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

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

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

lo/lou,min = lb/d = 1.00

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

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

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

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

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

with fsv = fs = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17529176

2 = Asl,com/(b*d)*(fs2/fc) = 0.17529176

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08498995$$

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 32.82928$$

$$c_c (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.23295708$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.23295708$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.11294889$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.23279566$$

$$M_u = M_{Rc} (4.14) = 1.3221E+008$$

$$u = s_u (4.1) = 0.0002015$$

Calculation of ratio l_b/d

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

Calculation of M_{u2} -

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

$$u = 0.0002015$$

$$M_u = 1.3221E+008$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00150304$$

$$N = 4666.932$$

$$f_c = 30.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01290198$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01290198$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$$

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

$$f_x = 0.0541155$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 882.7518$$

$$f_y = 0.09723711$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 793.0837$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \text{Cos}(\beta_1) = 1.016$$

fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.05494666
bo = 440.00
ho = 190.00
bi2 = 459400.00

psh,min = Min(psh,x , psh,y) = 0.00314159

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) = 0.00314159
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431

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

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

lo/lou,min = lb/d = 1.00

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

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

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

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

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

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

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

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

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

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

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

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

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

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

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

lo/lou,min = lb/d = 1.00

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

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

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

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

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

with $fsv = fs = 656.25$

with $Esv = Es = 200000.00$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.17529176$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.17529176$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.08498995$$

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 32.82928$$

$$cc (5A.5, TBDY) = 0.00294309$$

$c =$ confinement factor $= 1.09431$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.23295708$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.23295708$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.11294889$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

$$su (4.9) = 0.23279566$$

$$Mu = MRc (4.14) = 1.3221E+008$$

$$u = su (4.1) = 0.0002015$$

Calculation of ratio lb/d

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

Calculation of Shear Strength $Vr = Min(Vr1, Vr2) = 405928.36$

Calculation of Shear Strength at edge 1, $Vr1 = 405928.36$

$Vr1 = VCol$ ((10.3), ASCE 41-17) $= knl * VCol0$

$$VCol0 = 405928.36$$

$knl = 1$ (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)

$$fc' = 30.00, \text{ but } fc^{0.5} < 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/d = 2.00$$

$$Mu = 4.7466732E-012$$

$$Vu = 1.0405794E-032$$

$$d = 0.8 * h = 200.00$$

$$Nu = 4666.932$$

$$Ag = 125000.00$$

From (11.5.4.8), ACI 318-14: $Vs = 164933.614$

$$Av = 157079.633$$

$$fy = 525.00$$

$$s = 100.00$$

Vs is multiplied by $Col = 1.00$

$$s/d = 0.50$$

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

$f = 0.95$, 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 $V_f(\theta)$, 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: $\theta = 45^\circ$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, 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: $V_s + V_f \leq 363854.192$

$b_w = 500.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 405928.36$

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

$V_{Col0} = 405928.36$

$k_n l = 1$ (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).

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

$f_c' = 30.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / V d = 2.00$

$\mu_u = 4.7466732E-012$

$\nu_u = 1.0405794E-032$

$d = 0.8 \cdot h = 200.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 164933.614$

$A_v = 157079.633$

$f_y = 525.00$

$s = 100.00$

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

$s / d = 0.50$

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 α 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: $\theta = 45^\circ$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, 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: $V_s + V_f \leq 363854.192$

$b_w = 500.00$

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, $\phi = 0.85$
Mean strength values are used for both shear and moment calculations.
Consequently:
New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$
Concrete Elasticity, $E_c = 25742.96$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 656.25$

Section Height, $H = 250.00$
Section Width, $W = 500.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.09431
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou, \min} >= 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
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, $V_a = -7.3955710E-032$
EDGE -B-
Shear Force, $V_b = 7.3955710E-032$
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, $V_e/V_r = 0.47977838$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 240479.187$
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 3.6072E+008$
 $M_{u1+} = 3.6072E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $M_{u1-} = 3.6072E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 3.6072E+008$

Mu2+ = 3.6072E+008, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

Mu2- = 3.6072E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu1+

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

$$\mu = 8.4581924E-005$$

$$Mu = 3.6072E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00136161$$

$$N = 4666.932$$

$$f_c = 30.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01290198$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01290198$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$$

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

$$f_x = 0.0541155$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$f_y = 0.09723711$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 793.0837$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(\beta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.00314159$$

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

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

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00628319$$

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

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

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{yve} = 656.25$$

$$f_{ce} = 30.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00294309$

$$c = \text{confinement factor} = 1.09431$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$$fy_1 = 656.25$$

$$su_1 = 0.032$$

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

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

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

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

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

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

$$\text{with } fs_1 = fs = 656.25$$

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

$$y_2 = 0.0025$$

$$sh_2 = 0.008$$

$$ft_2 = 787.50$$

$$fy_2 = 656.25$$

$$su_2 = 0.032$$

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

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

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

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

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

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

$$\text{with } fs_2 = fs = 656.25$$

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

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$fy_v = 656.25$$

$$suv = 0.032$$

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

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

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

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

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

For calculation of $esuv_{, \text{nominal}}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsyv = fsv/1.2$, 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.

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

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

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.15879823$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.15879823$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.07699308$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, \text{TBDY}) = 32.82928$$

$$cc (5A.5, \text{TBDY}) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.22362502$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.22362502$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.10842425$$

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

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

s_u (4.8) = 0.17214129
 $M_u = M_{Rc}$ (4.15) = 3.6072E+008
 $u = s_u$ (4.1) = 8.4581924E-005

Calculation of ratio l_b/l_d

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

Calculation of M_{u1} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 8.4581924E-005$
 $M_u = 3.6072E+008$

with full section properties:

$b = 250.00$
 $d = 457.00$
 $d' = 43.00$
 $v = 0.00136161$
 $N = 4666.932$
 $f_c = 30.00$
 α (5A.5, TBDY) = 0.002
Final value of α : $\alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01290198$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\alpha = 0.01290198$
 ω ((5.4c), TBDY) = $\alpha * s_h * \text{min}(f_{ywe}/f_{ce} + \text{Min}(f_x, f_y)) = 0.05524832$
where $f = \alpha * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.0541155$
 $\alpha_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$
From EC8 A 4.4.3(6), $p_f = 2t_f/b_w = 0.004064$
 $b_w = 500.00$
effective stress from (A.35), $f_{f,e} = 882.7518$

$f_y = 0.09723711$
 $\alpha_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$
From EC8 A 4.4.3(6), $p_f = 2t_f/b_w = 0.008128$
 $b_w = 250.00$
effective stress from (A.35), $f_{f,e} = 793.0837$

$R = 40.00$
Effective FRP thickness, $t_f = N L^* t \text{Cos}(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{f,e} = 0.015$
 α_{se} ((5.4d), TBDY) = 0.05494666
 $b_o = 440.00$
 $h_o = 190.00$
 $b_i^2 = 459400.00$
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$

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) = 0.00314159
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431

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

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

lo/lou,min = lb/d = 1.00

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

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

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

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

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

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

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

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

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

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

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

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

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

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

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

lo/lou,min = lb/d = 1.00

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

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

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

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

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

with fsv = fs = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.15879823

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.15879823$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07699308$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 32.82928$$

$$c_c (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22362502$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.22362502$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.10842425$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

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

--->

$$s_u (4.8) = 0.17214129$$

$$\mu_u = M R_c (4.15) = 3.6072E+008$$

$$u = s_u (4.1) = 8.4581924E-005$$

Calculation of ratio l_b/d

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

Calculation of μ_{u2+}

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

$$u = 8.4581924E-005$$

$$\mu_u = 3.6072E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00136161$$

$$N = 4666.932$$

$$f_c = 30.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01290198$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01290198$$

$$w_e ((5.4c), TBDY) = a_s e^* s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$$

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

$$f_x = 0.0541155$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$f_y = 0.09723711$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 793.0837$$

R = 40.00
Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase((5.4d), TBDY) = 0.05494666$
 $bo = 440.00$
 $ho = 190.00$
 $bi_2 = 459400.00$
 $psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00314159$

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)

$psh_{,x}(5.4d) = 0.00314159$
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $bk = 500.00$

$psh_{,y}(5.4d) = 0.00628319$
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $bk = 250.00$

$s = 100.00$
 $fy_{we} = 656.25$
 $f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00294309$
 $c = \text{confinement factor} = 1.09431$

$y_1 = 0.0025$
 $sh_1 = 0.008$
 $ft_1 = 787.50$
 $fy_1 = 656.25$
 $su_1 = 0.032$

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

$lo/lo_{,min} = lb/ld = 1.00$

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

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

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$

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

$lo/lo_{,min} = lb/lb_{,min} = 1.00$

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

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

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

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

with $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $fy_v = 656.25$
 $suv = 0.032$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lo_{u,min} = lb/d = 1.00

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

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

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

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

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

with fsv = fs = 656.25

with Es_v = Es = 200000.00

1 = Asl_{ten}/(b*d)*(fs₁/fc) = 0.15879823

2 = Asl_{com}/(b*d)*(fs₂/fc) = 0.15879823

v = Asl_{mid}/(b*d)*(fsv/fc) = 0.07699308

and confined core properties:

b = 190.00

d = 427.00

d' = 13.00

fcc (5A.2, TBDY) = 32.82928

cc (5A.5, TBDY) = 0.00294309

c = confinement factor = 1.09431

1 = Asl_{ten}/(b*d)*(fs₁/fc) = 0.22362502

2 = Asl_{com}/(b*d)*(fs₂/fc) = 0.22362502

v = Asl_{mid}/(b*d)*(fsv/fc) = 0.10842425

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

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

--->

su (4.8) = 0.17214129

Mu = MRc (4.15) = 3.6072E+008

u = su (4.1) = 8.4581924E-005

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu₂-

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

u = 8.4581924E-005

Mu = 3.6072E+008

with full section properties:

b = 250.00

d = 457.00

d' = 43.00

v = 0.00136161

N = 4666.932

fc = 30.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01290198

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

From (5.4b), TBDY: cu = 0.01290198

we ((5.4c), TBDY) = ase* sh_{min}*fy_{we}/f_{ce}+Min(fx, fy) = 0.05524832

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

fx = 0.0541155

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), $ff,e = 882.7518$

fy = 0.09723711
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), $ff,e = 793.0837$

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) = 0.05494666
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.00314159
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) = 0.00314159
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00
From ((5.A5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431
y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

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

y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $es_{u2_nominal} = 0.08$,
 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 $fs_2 = fs = 656.25$
 with $Es_2 = Es = 200000.00$

$y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $fy_v = 656.25$
 $suv = 0.032$

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

$lo/lo_{u,min} = lb/d = 1.00$
 $suv = 0.4 \cdot es_{u2_nominal} ((5.5), TBDY) = 0.032$

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 $fs_v = fs = 656.25$
 with $Es_v = Es = 200000.00$

$1 = As_{l,ten}/(b \cdot d) \cdot (fs_1/fc) = 0.15879823$
 $2 = As_{l,com}/(b \cdot d) \cdot (fs_2/fc) = 0.15879823$
 $v = As_{l,mid}/(b \cdot d) \cdot (fs_v/fc) = 0.07699308$

and confined core properties:

$b = 190.00$
 $d = 427.00$
 $d' = 13.00$

$f_{cc} (5A.2, TBDY) = 32.82928$

$cc (5A.5, TBDY) = 0.00294309$

$c = \text{confinement factor} = 1.09431$

$1 = As_{l,ten}/(b \cdot d) \cdot (fs_1/fc) = 0.22362502$

$2 = As_{l,com}/(b \cdot d) \cdot (fs_2/fc) = 0.22362502$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/fc) = 0.10842425$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

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

--->

$su (4.8) = 0.17214129$

$Mu = MRc (4.15) = 3.6072E+008$

$u = su (4.1) = 8.4581924E-005$

 Calculation of ratio lb/d

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

 Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 501229.73$

Calculation of Shear Strength at edge 1, $V_{r1} = 501229.73$

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

$V_{Col0} = 501229.73$

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

 NOTE: In expression (10-3) ' $V_s = A_v \cdot fy \cdot d/s$ ' 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)

$fc' = 30.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$\mu_u = 5.0983467E-013$$

$$\mu_v = 7.3955710E-032$$

$$d = 0.8 \cdot h = 400.00$$

$$N_u = 4666.932$$

$$A_g = 125000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 329867.229$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

$$V_s \text{ is multiplied by } \phi_{col} = 1.00$$

$$s/d = 0.25$$

$$V_f \text{ ((11-3)-(11.4), ACI 440) } = 240803.347$$

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

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

In (11.3) $\sin \theta + \cos \theta$ 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.

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

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

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

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

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 363854.192$$

$$b_w = 250.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 501229.73$

$$V_{r2} = V_{col} \text{ ((10.3), ASCE 41-17) } = k_{nl} \cdot V_{col0}$$

$$V_{col0} = 501229.73$$

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

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).

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

$$f_c' = 30.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$\mu_u = 5.0983467E-013$$

$$\mu_v = 7.3955710E-032$$

$$d = 0.8 \cdot h = 400.00$$

$$N_u = 4666.932$$

$$A_g = 125000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 329867.229$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

$$V_s \text{ is multiplied by } \phi_{col} = 1.00$$

$$s/d = 0.25$$

$$V_f \text{ ((11-3)-(11.4), ACI 440) } = 240803.347$$

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

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

In (11.3) $\sin \theta + \cos \theta$ 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.

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

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

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

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

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

$$E_f = 64828.00$$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 363854.192$

$b_w = 250.00$

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: (b)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\phi = 0.85$

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

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

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/d \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -1.0374225E-010$

Shear Force, $V_2 = 3769.985$

Shear Force, $V_3 = 1.2662512E-013$

Axial Force, $F = -4665.423$

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, $Db_L = 18.66667$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u, R = 1.0^* u = 0.01423028$
 $u = y + p = 0.01423028$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00923028$ ((4.29), Biskinis Phd)
 $M_y = 9.2818E+007$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 5.0279E+012$
factor = 0.30
Ag = 125000.00
fc' = 30.00
N = 4665.423
 $E_c * I_g = 1.6760E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 1.8256818E-005$
with $f_y = 525.00$
d = 207.00
y = 0.30540146
A = 0.01999779
B = 0.01210997
with $p_t = 0.00801334$
pc = 0.00801334
pv = 0.00388525
N = 4665.423
b = 500.00
" = 0.20772947
 $y_{comp} = 3.3724871E-005$
with fc^* (12.3, (ACI 440)) = 30.44529
fc = 30.00
fl = 0.9425867
b = 500.00
h = 250.00
Ag = 125000.00
From (12.9), ACI 440: $k_a = 0.1506892$
g = $p_t + pc + pv = 0.01991193$
rc = 40.00
Ae/Ac = 0.60275679
Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
fu = 0.01
Ef = 64828.00
Ec = 25742.96
y = 0.30493935
A = 0.01980606
B = 0.01202411
with $E_s = 200000.00$

Calculation of ratio l_b / l_d

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

- Calculation of p -

From table 10-8: $p = 0.005$

with:

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

shear control ratio $V_y E / V_{CoI} E = 0.21712381$

$d = 207.00$

$s = 0.00$

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

$A_v = 157.0796$, 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 $t_f = 2 * t_f / b w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises t_f to steel strength

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

$NUD = 4665.423$

$A_g = 125000.00$

$f_{cE} = 30.00$

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

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

$b = 500.00$

$d = 207.00$

$f_{cE} = 30.00$

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

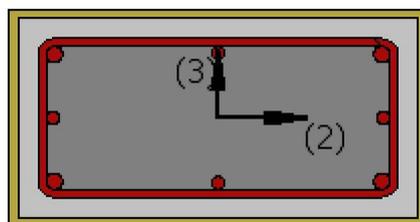
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

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, $\gamma = 0.85$

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

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

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 20.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 420.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

#####

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

New material: Concrete Strength, $f_c = f_{cm} = 30.00$

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $bi: 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = 4.8412113E-010$

Shear Force, $V_a = -1.2662512E-013$

EDGE -B-

Bending Moment, $M_b = -1.0374225E-010$

Shear Force, $V_b = 1.2662512E-013$

BOTH EDGES

Axial Force, $F = -4665.423$

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, $Db_{L,ten} = 18.66667$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $VR = 1.0 \cdot V_n = 347902.448$

$V_n ((10.3), ASCE 41-17) = knl \cdot V_{ColO} = 347902.448$

$V_{Col} = 347902.448$

$knl = 1.00$

displacement_ductility_demand = 0.00

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' 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)

$M/Vd = 2.00$

$\mu_u = 1.0374225E-010$

$\nu_u = 1.2662512E-013$

$d = 0.8 \cdot h = 200.00$

$N_u = 4665.423$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 131946.891$

$A_v = 157079.633$

$f_y = 420.00$

$s = 100.00$

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

$s/d = 0.50$

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

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

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

$d_{fv} = d$ (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: $V_s + V_f \leq 297085.704$

$b_w = 500.00$

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 $\theta = 2.0680189E-020$

$y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00923028$ ((4.29), Biskinis Phd)

$M_y = 9.2818E+007$

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

From table 10.5, ASCE 41_17: $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 5.0279E+012$

factor = 0.30

$A_g = 125000.00$

$f_c' = 30.00$

$N = 4665.423$

$E_c \cdot I_g = 1.6760E+013$

Calculation of Yielding Moment M_y

Calculation of δ and M_y according to Annex 7 -

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

$y_{\text{ten}} = 1.8256818E-005$

with $f_y = 525.00$

$d = 207.00$

$y = 0.30540146$

$A = 0.01999779$

B = 0.01210997
with pt = 0.00801334
pc = 0.00801334
pv = 0.00388525
N = 4665.423
b = 500.00
" = 0.20772947
y_comp = 3.3724871E-005
with fc* (12.3, (ACI 440)) = 30.44529
fc = 30.00
fl = 0.9425867
b = 500.00
h = 250.00
Ag = 125000.00
From (12.9), ACI 440: ka = 0.1506892
g = pt + pc + pv = 0.01991193
rc = 40.00
Ae/Ac = 0.60275679
Effective FRP thickness, tf = NL*t*Cos(b1) = 1.016
effective strain from (12.5) and (12.12), efe = 0.004
fu = 0.01
Ef = 64828.00
Ec = 25742.96
y = 0.30493935
A = 0.01980606
B = 0.01202411
with Es = 200000.00

Calculation of ratio lb/l_d

Adequate Lap Length: lb/l_d >= 1

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

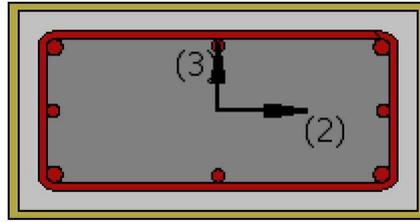
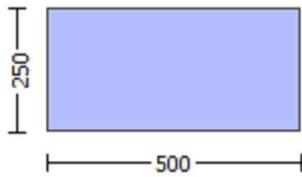
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (u)

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, $\gamma = 0.85$

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

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.09431

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou, \min} >= 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = -1.0405794E-032$

EDGE -B-

Shear Force, $V_b = 1.0405794E-032$

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 , $V_e/V_r = 0.21712381$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 88136.71$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.3221E+008$

$M_{u1+} = 1.3221E+008$, 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

$M_{u1-} = 1.3221E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.3221E+008$

$M_{u2+} = 1.3221E+008$, 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

$M_{u2-} = 1.3221E+008$, 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:

$\phi_u = 0.0002015$

$M_u = 1.3221E+008$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00150304$

$N = 4666.932$

$f_c = 30.00$

ϕ_c (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01290198$

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

From (5.4b), TBDY: $\phi_u = 0.01290198$

ω_e ((5.4c), TBDY) = $\alpha_s e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$

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

$f_x = 0.0541155$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

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

$b_w = 500.00$

effective stress from (A.35), $f_{fe} = 882.7518$

$f_y = 0.09723711$

$\alpha_f = 0.45253333$

$b = 250.00$

$h = 500.00$

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

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 793.0837$

$R = 40.00$

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

fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.05494666
bo = 440.00
ho = 190.00
bi2 = 459400.00

psh,min = Min(psh,x , psh,y) = 0.00314159

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) = 0.00314159
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431

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

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

lo/lou,min = lb/lb = 1.00

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

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

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

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

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

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

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

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

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

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

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

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

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

yv = 0.0025
shv = 0.008
ftv = 787.50
fyv = 656.25
suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_nominal$ and yv , shv,ftv,fyv , it is considered characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1$, $sh1,ft1,fy1$, are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fsv = fs = 656.25$

with $Esv = Es = 200000.00$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.17529176$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.17529176$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.08498995$$

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 32.82928$$

$$cc (5A.5, TBDY) = 0.00294309$$

c = confinement factor = 1.09431

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.23295708$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.23295708$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.11294889$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs,y2$ - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.23279566$$

$$Mu = MRc (4.14) = 1.3221E+008$$

$$u = su (4.1) = 0.0002015$$

Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of $Mu1$ -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 0.0002015$$

$$Mu = 1.3221E+008$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00150304$$

$$N = 4666.932$$

$$fc = 30.00$$

$$co (5A.5, TBDY) = 0.002$$

Final value of cu : $cu^* = shear_factor * Max(cu, cc) = 0.01290198$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01290198$

we ((5.4c), TBDY) = $ase * sh,min * fywe / fce + Min(fx, fy) = 0.05524832$

where $f = af * pf * ffe / fce$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$fx = 0.0541155$$

$$af = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

$$bw = 500.00$$

effective stress from (A.35), $ffe = 882.7518$

$f_y = 0.09723711$
 $a_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$
From EC8 A4.4.3(6), $p_f = 2t_f/b_w = 0.008128$
 $b_w = 250.00$
effective stress from (A.35), $f_{f,e} = 793.0837$

 $R = 40.00$
Effective FRP thickness, $t_f = NL*t*\cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $a_{se} \text{ ((5.4d), TBDY)} = 0.05494666$
 $b_o = 440.00$
 $h_o = 190.00$
 $b_{i2} = 459400.00$
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$

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)

 $p_{sh,x} \text{ (5.4d)} = 0.00314159$
 $A_{sh} = A_{stir}*n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $b_k = 500.00$

 $p_{sh,y} \text{ (5.4d)} = 0.00628319$
 $A_{sh} = A_{stir}*n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $b_k = 250.00$

 $s = 100.00$
 $f_{ywe} = 656.25$
 $f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.00294309$
 $c = \text{confinement factor} = 1.09431$

$y_1 = 0.0025$
 $sh_1 = 0.008$
 $ft_1 = 787.50$
 $fy_1 = 656.25$
 $su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$su_1 = 0.4*esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25*(l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4*esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25*(l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 656.25$

with $E_s2 = E_s = 200000.00$
 $y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $fy_v = 656.25$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/ld = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 656.25$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b * d) * (fs1/fc) = 0.17529176$
 $2 = Asl_{com}/(b * d) * (fs2/fc) = 0.17529176$
 $v = Asl_{mid}/(b * d) * (fsv/fc) = 0.08498995$
 and confined core properties:
 $b = 440.00$
 $d = 177.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 32.82928$
 $cc (5A.5, TBDY) = 0.00294309$
 $c = \text{confinement factor} = 1.09431$
 $1 = Asl_{ten}/(b * d) * (fs1/fc) = 0.23295708$
 $2 = Asl_{com}/(b * d) * (fs2/fc) = 0.23295708$
 $v = Asl_{mid}/(b * d) * (fsv/fc) = 0.11294889$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs_{y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.23279566$
 $Mu = MRc (4.14) = 1.3221E+008$
 $u = su (4.1) = 0.0002015$

 Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of Mu_{2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 0.0002015$
 $Mu = 1.3221E+008$

with full section properties:

$b = 500.00$
 $d = 207.00$
 $d' = 43.00$
 $v = 0.00150304$
 $N = 4666.932$
 $fc = 30.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01290198$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01290198$
 $we ((5.4c), TBDY) = ase * sh_{min} * fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.05524832$

where $f = af*pf*ffe/fce$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$fx = 0.0541155$$

$$af = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } ff,e = 882.7518$$

$$fy = 0.09723711$$

$$af = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff,e = 793.0837$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } tf = NL*t*\text{Cos}(b1) = 1.016$$

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$\text{ase ((5.4d), TBDY) = 0.05494666}$$

$$bo = 440.00$$

$$ho = 190.00$$

$$bi2 = 459400.00$$

$$\text{psh,min} = \text{Min}(\text{psh,x}, \text{psh,y}) = 0.00314159$$

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\text{psh,x (5.4d) = 0.00314159}$$

$$\text{Ash} = \text{Astir}*ns = 78.53982$$

$$\text{No stirrups, } ns = 2.00$$

$$bk = 500.00$$

$$\text{psh,y (5.4d) = 0.00628319}$$

$$\text{Ash} = \text{Astir}*ns = 78.53982$$

$$\text{No stirrups, } ns = 2.00$$

$$bk = 250.00$$

$$s = 100.00$$

$$fywe = 656.25$$

$$fce = 30.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 787.50$$

$$fy1 = 656.25$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/ld = 1.00$$

$$su1 = 0.4*esu1_nominal \text{ ((5.5), TBDY) = 0.032}$$

$$\text{From table 5A.1, TBDY: } esu1_nominal = 0.08,$$

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

$$y1, sh1,ft1,fy1, \text{ are also multiplied by } \text{Min}(1, 1.25*(lb/ld)^{2/3}), \text{ from 10.3.5, ASCE41-17.}$$

$$\text{with } fs1 = fs = 656.25$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.0025$$

$$sh2 = 0.008$$

$$ft2 = 787.50$$

$$fy2 = 656.25$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

yv = 0.0025

shv = 0.008

ftv = 787.50

fyv = 656.25

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17529176

2 = Asl,com/(b*d)*(fs2/fc) = 0.17529176

v = Asl,mid/(b*d)*(fsv/fc) = 0.08498995

and confined core properties:

b = 440.00

d = 177.00

d' = 13.00

fcc (5A.2, TBDY) = 32.82928

cc (5A.5, TBDY) = 0.00294309

c = confinement factor = 1.09431

1 = Asl,ten/(b*d)*(fs1/fc) = 0.23295708

2 = Asl,com/(b*d)*(fs2/fc) = 0.23295708

v = Asl,mid/(b*d)*(fsv/fc) = 0.11294889

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.23279566

Mu = MRc (4.14) = 1.3221E+008

u = su (4.1) = 0.0002015

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 0.0002015

Mu = 1.3221E+008

with full section properties:

b = 500.00

d = 207.00

d' = 43.00

v = 0.00150304

N = 4666.932

fc = 30.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01290198$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01290198$

we ((5.4c), TBDY) = $ase * sh_{\min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.05524832$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.0541155

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), $ff_e = 882.7518$

fy = 0.09723711

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), $ff_e = 793.0837$

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) = 0.05494666

bo = 440.00

ho = 190.00

bi2 = 459400.00

psh,min = $\text{Min}(psh_x, psh_y) = 0.00314159$

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) = 0.00314159

Ash = $A_{stir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 500.00

psh,y (5.4d) = 0.00628319

Ash = $A_{stir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 250.00

s = 100.00

fywe = 656.25

fce = 30.00

From ((5.A5), TBDY), TBDY: $cc = 0.00294309$

c = confinement factor = 1.09431

y1 = 0.0025

sh1 = 0.008

ft1 = 787.50

fy1 = 656.25

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = $lb/d = 1.00$

su1 = $0.4 * esu1_{\text{nominal}} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu1_{\text{nominal}} = 0.08,$

For calculation of $es_{u1_nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fs_{y1} = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$fy_2 = 656.25$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{ou,min} = lb/lb_{,min} = 1.00$

$su_2 = 0.4 \cdot es_{u2_nominal} ((5.5), TBDY) = 0.032$

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_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$fy_v = 656.25$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{ou,min} = lb/ld = 1.00$

$su_v = 0.4 \cdot es_{uv_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,

considering characteristic value $fs_{yv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $es_{uv_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered characteristic value $fs_{yv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = fs = 656.25$

with $Es_v = Es = 200000.00$

1 = $Asl_{,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.17529176$

2 = $Asl_{,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.17529176$

v = $Asl_{,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08498995$

and confined core properties:

$b = 440.00$

$d = 177.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 32.82928$

$cc (5A.5, TBDY) = 0.00294309$

c = confinement factor = 1.09431

1 = $Asl_{,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.23295708$

2 = $Asl_{,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.23295708$

v = $Asl_{,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.11294889$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.23279566$

$\mu = MR_c (4.14) = 1.3221E+008$

$u = su (4.1) = 0.0002015$

Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 405928.36$

Calculation of Shear Strength at edge 1, $V_{r1} = 405928.36$

$V_{r1} = V_{CoI} ((10.3), \text{ASCE } 41-17) = knl * V_{CoI0}$

$V_{CoI0} = 405928.36$

$knl = 1$ (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)

$f_c' = 30.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$M_u = 4.7466732E-012$

$V_u = 1.0405794E-032$

$d = 0.8 * h = 200.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 164933.614$

$A_v = 157079.633$

$f_y = 525.00$

$s = 100.00$

V_s is multiplied by $Col = 1.00$

$s/d = 0.50$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 109072.851$

$f = 0.95$, for fully-wrapped sections

$w_f / s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 207.00

$f_{fe} ((11-5), \text{ACI } 440) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 363854.192$

$bw = 500.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 405928.36$

$V_{r2} = V_{CoI} ((10.3), \text{ASCE } 41-17) = knl * V_{CoI0}$

$V_{CoI0} = 405928.36$

$knl = 1$ (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)

$f_c' = 30.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$M_u = 4.7466732E-012$

$V_u = 1.0405794E-032$

$d = 0.8 * h = 200.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 164933.614$

$A_v = 157079.633$

$f_y = 525.00$

$s = 100.00$

V_s is multiplied by $Col = 1.00$

$s/d = 0.50$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 109072.851$

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 $V_f(\theta)$, 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, $t_{f1} = NL * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (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: $V_s + V_f \leq 363854.192$
 $bw = 500.00$

 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, $\gamma = 0.85$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$
 Concrete Elasticity, $E_c = 25742.96$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 New material: Steel Strength, $f_s = 1.25 * f_{sm} = 656.25$
 #####
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.09431
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{ou}, \text{min} >= 1$)
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $\text{NoDir} = 1$
 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, $V_a = -7.3955710E-032$

EDGE -B-

Shear Force, $V_b = 7.3955710E-032$

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: $As_{l,mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.47977838$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 240479.187$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 3.6072E+008$

$Mu_{1+} = 3.6072E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 3.6072E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 3.6072E+008$

$Mu_{2+} = 3.6072E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$Mu_{2-} = 3.6072E+008$, 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:

$\phi_u = 8.4581924E-005$

$M_u = 3.6072E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00136161$

$N = 4666.932$

$f_c = 30.00$

α_c (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01290198$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01290198$

where ϕ_u ((5.4c), TBDY) = $\alpha_c * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.05524832$

where $\phi = \alpha_c * \text{pf} * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.0541155$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 882.7518$

$f_y = 0.09723711$

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), $ff,e = 793.0837$

R = 40.00
Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase \text{ ((5.4d), TBDY)} = 0.05494666$
bo = 440.00
ho = 190.00
bi2 = 459400.00
 $psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00314159$

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)

$psh_{,x} \text{ (5.4d)} = 0.00314159$
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

$psh_{,y} \text{ (5.4d)} = 0.00628319$
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 100.00
 $fy_{we} = 656.25$
fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431

y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 656.25$

with $Es1 = Es = 200000.00$

y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 656.25$

with $Es2 = Es = 200000.00$

yv = 0.0025
shv = 0.008
ftv = 787.50
fyv = 656.25
suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.15879823

2 = Asl,com/(b*d)*(fs2/fc) = 0.15879823

v = Asl,mid/(b*d)*(fsv/fc) = 0.07699308

and confined core properties:

b = 190.00

d = 427.00

d' = 13.00

fcc (5A.2, TBDY) = 32.82928

cc (5A.5, TBDY) = 0.00294309

c = confinement factor = 1.09431

1 = Asl,ten/(b*d)*(fs1/fc) = 0.22362502

2 = Asl,com/(b*d)*(fs2/fc) = 0.22362502

v = Asl,mid/(b*d)*(fsv/fc) = 0.10842425

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

v < vs,y2 - LHS eq.(4.5) is not satisfied

v < vs,c - RHS eq.(4.5) is satisfied

su (4.8) = 0.17214129

Mu = MRc (4.15) = 3.6072E+008

u = su (4.1) = 8.4581924E-005

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 8.4581924E-005

Mu = 3.6072E+008

with full section properties:

b = 250.00

d = 457.00

d' = 43.00

v = 0.00136161

N = 4666.932

fc = 30.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01290198

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01290198

$w_e ((5.4c), TBDY) = a_{se} * sh_{min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$
where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.0541155$
 $a_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$
From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.004064$
 $bw = 500.00$
effective stress from (A.35), $f_{f,e} = 882.7518$

$f_y = 0.09723711$
 $a_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$
From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.008128$
 $bw = 250.00$
effective stress from (A.35), $f_{f,e} = 793.0837$

$R = 40.00$
Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $a_{se} ((5.4d), TBDY) = 0.05494666$
 $b_o = 440.00$
 $h_o = 190.00$
 $b_{i2} = 459400.00$

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$
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)

$p_{sh,x} (5.4d) = 0.00314159$
 $A_{sh} = A_{stir} * n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $b_k = 500.00$

$p_{sh,y} (5.4d) = 0.00628319$
 $A_{sh} = A_{stir} * n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $b_k = 250.00$

$s = 100.00$
 $f_{ywe} = 656.25$
 $f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00294309$
 $c = \text{confinement factor} = 1.09431$

$y_1 = 0.0025$
 $sh_1 = 0.008$
 $ft_1 = 787.50$
 $fy_1 = 656.25$
 $su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/lb_{u,min} = 1.00$$

$$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fs_2 = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 656.25$$

$$\text{with } Es_2 = Es = 200000.00$$

$$yv = 0.0025$$

$$shv = 0.008$$

$$ftv = 787.50$$

$$fyv = 656.25$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/ld = 1.00$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $fsv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_{nominal}$ and yv, shv, ftv, fyv , it is considered
characteristic value $fsv = fsv/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 656.25$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.15879823$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.15879823$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.07699308$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 32.82928$$

$$cc (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.22362502$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.22362502$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.10842425$$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

---->

$v < vs_{y2}$ - LHS eq.(4.5) is not satisfied

---->

$v < vs_c$ - RHS eq.(4.5) is satisfied

---->

$$su (4.8) = 0.17214129$$

$$Mu = MRc (4.15) = 3.6072E+008$$

$$u = su (4.1) = 8.4581924E-005$$

Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of Mu_{2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 8.4581924E-005$$

$$Mu = 3.6072E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00136161$$

$$N = 4666.932$$

$$f_c = 30.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01290198$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01290198$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0541155$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$f_y = 0.09723711$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 793.0837$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.00314159$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00628319$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 30.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$$fy_1 = 656.25$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 1.00$$

$$s_u1 = 0.4 * e_{s1_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s1_nominal} = 0.08$,

For calculation of $e_{s1_nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $f_{sy1} = f_{s1}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s1} = f_s = 656.25$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.0025$$

$$sh_2 = 0.008$$

$$ft_2 = 787.50$$

$$fy_2 = 656.25$$

$$s_u2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$$

$$s_u2 = 0.4 * e_{s2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s2_nominal} = 0.08$,

For calculation of $e_{s2_nominal}$ and y_2, sh_2, ft_2, 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.

$$\text{with } f_{s2} = f_s = 656.25$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$fy_v = 656.25$$

$$s_{u,v} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 1.00$$

$$s_{u,v} = 0.4 * e_{s_{u,v}_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s_{u,v}_nominal} = 0.08$,

considering characteristic value $f_{s_{y,v}} = f_{s_{v}}/1.2$, from table 5.1, TBDY

For calculation of $e_{s_{u,v}_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered characteristic value $f_{s_{y,v}} = f_{s_{v}}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s_{v}} = f_s = 656.25$$

$$\text{with } E_{s_{v}} = E_s = 200000.00$$

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.15879823$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.15879823$$

$$v = A_{s1,mid}/(b*d) * (f_{sv}/f_c) = 0.07699308$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 32.82928$$

$$c_c (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.22362502$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.22362502$$

$$v = A_{s1,mid}/(b*d) * (f_{sv}/f_c) = 0.10842425$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

--->

$$s_u (4.8) = 0.17214129$$

$$\mu_u = M_{Rc} (4.15) = 3.6072E+008$$

$$u = s_u (4.1) = 8.4581924E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_2

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 8.4581924E-005$$

$$\mu_2 = 3.6072E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00136161$$

$$N = 4666.932$$

$$f_c = 30.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_o) = 0.01290198$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.01290198$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0541155$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$f_y = 0.09723711$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 793.0837$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.00314159$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00628319$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 30.00$$

From (5.A.5), TBDY, TBDY: $cc = 0.00294309$

$$c = \text{confinement factor} = 1.09431$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$$fy_1 = 656.25$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 656.25$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.0025$$

$$sh_2 = 0.008$$

$$ft_2 = 787.50$$

$$fy_2 = 656.25$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_{b,min} = 1.00$$

$$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_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.

$$\text{with } fs_2 = fs = 656.25$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$fy_v = 656.25$$

$$su_v = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 1.00$$

$$su_v = 0.4 * esu_{v,nominal} ((5.5), TBDY) = 0.032$$

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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 656.25$$

$$\text{with } Es_v = Es = 200000.00$$

$$1 = Asl_{,ten}/(b*d) * (fs_1/fc) = 0.15879823$$

$$2 = Asl_{,com}/(b*d) * (fs_2/fc) = 0.15879823$$

$$v = Asl_{,mid}/(b*d) * (fsv/fc) = 0.07699308$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 32.82928$$

$$cc (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = Asl_{,ten}/(b*d) * (fs_1/fc) = 0.22362502$$

$$2 = Asl_{,com}/(b*d) * (fs_2/fc) = 0.22362502$$

$$v = Asl_{,mid}/(b*d) * (fsv/fc) = 0.10842425$$

Case/Assumption: Unconfinedsd full section - Steel rupture

satisfies Eq. (4.3)

---->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

---->

$$s_u(4.8) = 0.17214129$$

$$\mu = M/R_c(4.15) = 3.6072E+008$$

$$u = s_u(4.1) = 8.4581924E-005$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 501229.73$

Calculation of Shear Strength at edge 1, $V_{r1} = 501229.73$

$$V_{r1} = V_{Col}((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$$

$$V_{Col0} = 501229.73$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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).

$$= 1 \text{ (normal-weight concrete)}$$

$$f_c' = 30.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/d = 2.00$$

$$\mu = 5.0983467E-013$$

$$V_u = 7.3955710E-032$$

$$d = 0.8 * h = 400.00$$

$$N_u = 4666.932$$

$$A_g = 125000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 329867.229$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

$$V_s \text{ is multiplied by } \lambda = 1.00$$

$$s/d = 0.25$$

$$V_f \text{ ((11-3)-(11.4), ACI 440) } = 240803.347$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$$w_f/s_f = 1 \text{ (FRP strips adjacent to one another).}$$

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

$$\text{orientation 1: } \theta = 45^\circ = 90.00$$

$$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = N_L * t / N_{oDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440) } = 457.00$$

$$f_{fe} \text{ ((11-5), ACI 440) } = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 363854.192$$

$$b_w = 250.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 501229.73$

$$V_{r2} = V_{Col}((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$$

$$V_{Col0} = 501229.73$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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)

$f_c' = 30.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 5.0983467E-013$

$V_u = 7.3955710E-032$

$d = 0.8 \cdot h = 400.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 329867.229$

$A_v = 157079.633$

$f_y = 525.00$

$s = 100.00$

V_s is multiplied by $\text{Col} = 1.00$

$s/d = 0.25$

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: $V_s + V_f \leq 363854.192$

$b_w = 250.00$

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, $\phi = 0.85$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/d \geq 1$)

FRP Wrapping Data

Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -0.00064216$
Shear Force, $V_2 = 3769.985$
Shear Force, $V_3 = 1.2662512E-013$
Axial Force, $F = -4665.423$
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, $DbL = 18.66667$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = 1.0^*$ $u = 0.00600229$
 $u = y + p = 0.00600229$

- Calculation of y -

$y = (My * L_s / 3) / E_{eff} = 0.00102938$ ((4.29), Biskinis Phd))
 $My = 2.0703E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 2.0112E+013$
 $factor = 0.30$
 $Ag = 125000.00$
 $fc' = 30.00$
 $N = 4665.423$
 $E_c * I_g = 6.7039E+013$

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 7.9424740E-006$
with $f_y = 525.00$
 $d = 457.00$
 $y = 0.27680185$
 $A = 0.01811616$
 $B = 0.0099456$
with $pt = 0.00725935$
 $pc = 0.00725935$
 $pv = 0.00351968$
 $N = 4665.423$
 $b = 250.00$
 $" = 0.0940919$
 $y_{comp} = 1.6862746E-005$
with $fc' (12.3, (ACI 440)) = 30.44585$

$f_c = 30.00$
 $f_l = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $A_g = 125000.00$
 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, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 25742.96$
 $y = 0.27624702$
 $A = 0.01794247$
 $B = 0.00986782$
 with $E_s = 200000.00$

 Calculation of ratio l_b/l_d

 Adequate Lap Length: $l_b/l_d \geq 1$

 - Calculation of p -

 From table 10-8: $p = 0.00497291$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$

shear control ratio $V_y E / V_c \rho_l \sigma_c = 0.47977838$

$d = 457.00$

$s = 0.00$

$t = A_v / (b_w \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00$

$A_v = 157.0796$, 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.

$NUD = 4665.423$

$A_g = 125000.00$

$f_c E = 30.00$

$f_{yE} = f_{yI} = 0.00$

$p_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.01803838$

$b = 250.00$

$d = 457.00$

$f_c E = 30.00$

 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

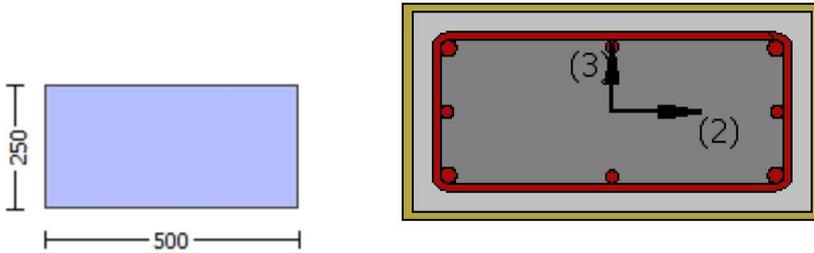
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity 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, $\gamma = 0.85$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 20.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 420.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

New material: Concrete Strength, $f_c = f_{cm} = 30.00$

New material: Steel Strength, $f_s = f_{sm} = 525.00$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou,min} = l_b/l_d \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $ef_u = 0.01$

Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

EDGE -A-
Bending Moment, Ma = -9.0652E+006
Shear Force, Va = -3021.16
EDGE -B-
Bending Moment, Mb = -0.00051461
Shear Force, Vb = 3021.16
BOTH EDGES
Axial Force, F = -4665.723
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
Mean Diameter of Tension Reinforcement, DbL,ten = 18.66667

New component: From table 7-7, ASCE 41_17: Final Shear Capacity VR = 1.0*Vn = 353253.908
Vn ((10.3), ASCE 41-17) = knl*VColO = 353253.908
VCol = 353253.908
knl = 1.00
displacement_ductility_demand = 0.01206354

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 = 4.00
Mu = 9.0652E+006
Vu = 3021.16
d = 0.8*h = 400.00
Nu = 4665.723
Ag = 125000.00
From (11.5.4.8), ACI 318-14: Vs = 263893.783
Av = 157079.633
fy = 420.00
s = 100.00
Vs is multiplied by Col = 1.00
s/d = 0.25
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 + 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) = 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

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 = 0.0001242
 $y = (M_y * L_s / 3) / E_{eff} = 0.01029579$ ((4.29), Biskinis Phd)
 $M_y = 2.0703E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3000.571
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 2.0112E+013$
factor = 0.30
 $A_g = 125000.00$
 $f_c' = 30.00$
 $N = 4665.723$
 $E_c * I_g = 6.7039E+013$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 7.9424748E-006$
with $f_y = 525.00$
 $d = 457.00$
 $y = 0.27680192$
 $A = 0.01811617$
 $B = 0.00994561$
with $p_t = 0.00725935$
 $p_c = 0.00725935$
 $p_v = 0.00351968$
 $N = 4665.723$
 $b = 250.00$
 $\alpha = 0.0940919$
 $y_{comp} = 1.6862744E-005$
with $f_c' (12.3, (ACI 440)) = 30.44585$
 $f_c = 30.00$
 $f_l = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $A_g = 125000.00$
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, $t_f = NL * t * \text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 25742.96$
 $y = 0.27624705$
 $A = 0.01794246$
 $B = 0.00986782$
with $E_s = 200000.00$

Calculation of ratio l_b / d

Adequate Lap Length: $l_b / d \geq 1$

End Of Calculation of Shear Capacity for element: column C1 of floor 1
At local axis: 2

Integration Section: (a)

Calculation No. 10

column C1, Floor 1

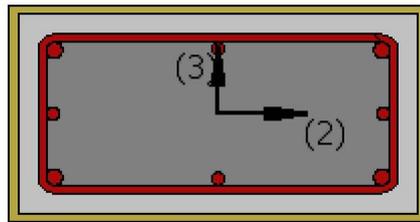
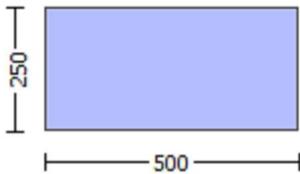
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

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, $\gamma = 0.85$

Mean strength values are used for both shear and moment calculations.

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.09431

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou, \min} \geq 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = -1.0405794E-032$
EDGE -B-
Shear Force, $V_b = 1.0405794E-032$
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: $As_{t, \text{ten}} = 829.3805$
-Compression: $As_{l, \text{com}} = 829.3805$
-Middle: $As_{l, \text{mid}} = 402.1239$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.21712381$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 88136.71$
with
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 1.3221E+008$
 $Mu_{1+} = 1.3221E+008$, 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
 $Mu_{1-} = 1.3221E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 1.3221E+008$
 $Mu_{2+} = 1.3221E+008$, 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
 $Mu_{2-} = 1.3221E+008$, 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:
 $\phi_u = 0.0002015$
 $M_u = 1.3221E+008$

with full section properties:

$b = 500.00$
 $d = 207.00$
 $d' = 43.00$
 $v = 0.00150304$
 $N = 4666.932$

$f_c = 30.00$

c_o (5A.5, TBDY) = 0.002

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01290198$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.01290198$

we ((5.4c), TBDY) = $ase * sh_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.0541155$

$af = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $ff,e = 882.7518$

 $f_y = 0.09723711$

$af = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff,e = 793.0837$

 $R = 40.00$

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) = 0.05494666

$bo = 440.00$

$ho = 190.00$

$bi2 = 459400.00$

$psh_{\min} = \text{Min}(psh_x, psh_y) = 0.00314159$

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) = 0.00314159

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$bk = 500.00$

 psh_y (5.4d) = 0.00628319

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$bk = 250.00$

 $s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00294309$

$c = \text{confinement factor} = 1.09431$

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 787.50$

$fy1 = 656.25$

$su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou_{\min} = lb/ld = 1.00$

$su1 = 0.4 * esu1_{\text{nominal}}$ ((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 $fs1 = fs = 656.25$

with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/lb_{min} = 1.00$
 $su_2 = 0.4 * esu_{2_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2_nominal} = 0.08$,
 For calculation of $esu_{2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fs_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 656.25$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $fy_v = 656.25$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/ld = 1.00$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fs_v = fs_v/1.2$, 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 $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_v = fs = 656.25$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/fc) = 0.17529176$
 $2 = A_{sl,com}/(b*d) * (fs_2/fc) = 0.17529176$
 $v = A_{sl,mid}/(b*d) * (fs_v/fc) = 0.08498995$
 and confined core properties:
 $b = 440.00$
 $d = 177.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 32.82928$
 $cc (5A.5, TBDY) = 0.00294309$
 $c = \text{confinement factor} = 1.09431$
 $1 = A_{sl,ten}/(b*d) * (fs_1/fc) = 0.23295708$
 $2 = A_{sl,com}/(b*d) * (fs_2/fc) = 0.23295708$
 $v = A_{sl,mid}/(b*d) * (fs_v/fc) = 0.11294889$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_s, y_2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.23279566$
 $Mu = MRc (4.14) = 1.3221E+008$
 $u = su (4.1) = 0.0002015$

 Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of Mu_1 -

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 0.0002015$$

$$\mu = 1.3221E+008$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00150304$$

$$N = 4666.932$$

$$f_c = 30.00$$

$$\alpha (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01290198$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01290198$$

$$\omega_e ((5.4c), \text{TBDY}) = \alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.05524832$$

where $\phi = \alpha * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.0541155$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 882.7518$$

$$\phi_y = 0.09723711$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 793.0837$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(\beta_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$\alpha_s_e ((5.4d), \text{TBDY}) = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$\text{psh}_{\min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.00314159$$

Expression ((5.4d), TBDY) for psh_{\min} has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\text{psh}_x (5.4d) = 0.00314159$$

$$A_{sh} = A_{\text{stir}} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$\text{psh}_y (5.4d) = 0.00628319$$

$$A_{sh} = A_{\text{stir}} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 30.00$$

$$\text{From ((5.A.5), TBDY), TBDY: } \phi_c = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$$fy_1 = 656.25$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$fy_2 = 656.25$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$fy_v = 656.25$

$suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_{nominal}$ and 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 $fsv = fs = 656.25$

with $Es_v = Es = 200000.00$

$1 = A_{sl,ten}/(b*d) * (fs_1/fc) = 0.17529176$

$2 = A_{sl,com}/(b*d) * (fs_2/fc) = 0.17529176$

$v = A_{sl,mid}/(b*d) * (fsv/fc) = 0.08498995$

and confined core properties:

$b = 440.00$

$d = 177.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 32.82928$

$cc (5A.5, TBDY) = 0.00294309$

$c = \text{confinement factor} = 1.09431$

$1 = A_{sl,ten}/(b*d) * (fs_1/fc) = 0.23295708$

$2 = A_{sl,com}/(b*d) * (fs_2/fc) = 0.23295708$

$v = A_{sl,mid}/(b*d) * (fsv/fc) = 0.11294889$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

---->

$su (4.9) = 0.23279566$

$\mu_u = M_{Rc} (4.14) = 1.3221E+008$

$u = su (4.1) = 0.0002015$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 0.0002015$$

$$\mu = 1.3221E+008$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00150304$$

$$N = 4666.932$$

$$f_c = 30.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01290198$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01290198$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0541155$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$f_y = 0.09723711$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 793.0837$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(\beta_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.00314159$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00628319$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 30.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00294309$

$$c = \text{confinement factor} = 1.09431$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$$fy_1 = 656.25$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 656.25$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.0025$$

$$sh_2 = 0.008$$

$$ft_2 = 787.50$$

$$fy_2 = 656.25$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$$

$$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 656.25$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$fy_v = 656.25$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 1.00$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 656.25$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.17529176$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.17529176$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.08498995$$

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 32.82928$$

$$cc (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.23295708$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.23295708$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.11294889$$

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) = 0.23279566
 μ_u = MRc (4.14) = 1.3221E+008
 u = s_u (4.1) = 0.0002015

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_{u2} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 0.0002015
 μ_u = 1.3221E+008

with full section properties:

b = 500.00
 d = 207.00
 d' = 43.00
 v = 0.00150304
 N = 4666.932
 f_c = 30.00
 α (5A.5, TBDY) = 0.002

Final value of α : $\alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01290198$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\alpha_c = 0.01290198$

α_{we} ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$

where $f = \alpha * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 f_x = 0.0541155
 α_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), $f_{fe} = 882.7518$

 f_y = 0.09723711
 α_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), $f_{fe} = 793.0837$

 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
 α_{se} ((5.4d), TBDY) = 0.05494666

b_o = 440.00
 h_o = 190.00
 b_{i2} = 459400.00

$p_{sh, \text{min}}$ = $\text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$

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)

psh,x (5.4d) = 0.00314159
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00

From ((5.A.5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431

y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

yv = 0.0025
shv = 0.008
ftv = 787.50
fyv = 656.25
suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.

with fsv = fs = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17529176

2 = Asl,com/(b*d)*(fs2/fc) = 0.17529176

v = Asl,mid/(b*d)*(fsv/fc) = 0.08498995

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 32.82928$$

$$cc (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.23295708$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.23295708$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.11294889$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.23279566$$

$$\mu = M_{Rc} (4.14) = 1.3221E+008$$

$$u = s_u (4.1) = 0.0002015$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 405928.36$

Calculation of Shear Strength at edge 1, $V_{r1} = 405928.36$

$$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$$

$$V_{Col0} = 405928.36$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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)

$$f_c' = 30.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$\mu = 4.7466732E-012$$

$$V_u = 1.0405794E-032$$

$$d = 0.8 * h = 200.00$$

$$N_u = 4666.932$$

$$A_g = 125000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 164933.614$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

V_s is multiplied by $\text{Col} = 1.00$

$$s/d = 0.50$$

$$V_f ((11-3)-(11.4), ACI 440) = 109072.851$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,

where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

$$\text{orientation 1: } \theta = 45^\circ + 90^\circ = 135^\circ$$

$$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = N_L * t / N_{oDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 207.00$$

$$f_{fe} ((11-5), ACI 440) = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 363854.192$$

bw = 500.00

Calculation of Shear Strength at edge 2, Vr2 = 405928.36

Vr2 = VCol ((10.3), ASCE 41-17) = knl*VCol0

VCol0 = 405928.36

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' = 30.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 4.7466732E-012

Vu = 1.0405794E-032

d = 0.8*h = 200.00

Nu = 4666.932

Ag = 125000.00

From (11.5.4.8), ACI 318-14: Vs = 164933.614

Av = 157079.633

fy = 525.00

s = 100.00

Vs is multiplied by Col = 1.00

s/d = 0.50

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(α), is implemented for every different fiber orientation ai, as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\alpha = b1 + 90^\circ = 90.00$

Vf = Min(|Vf(45, 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: Vs + Vf <= 363854.192

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, $\gamma = 0.85$

Mean strength values are used for both shear and moment calculations.

Consequently:

New material of Secondary Member: Concrete Strength, fc = fcm = 30.00

New material of Secondary Member: Steel Strength, fs = fsm = 525.00

Concrete Elasticity, Ec = 25742.96

Steel Elasticity, Es = 200000.00

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 656.25$
 #####
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.09431
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{ou}, \min > = 1$)
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $N_{oDir} = 1$
 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, $V_a = -7.3955710E-032$
 EDGE -B-
 Shear Force, $V_b = 7.3955710E-032$
 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 , $V_e/V_r = 0.47977838$
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 240479.187$
 with
 $M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 3.6072E+008$
 $M_{u1+} = 3.6072E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
 which is defined for the static loading combination
 $M_{u1-} = 3.6072E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
 direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 3.6072E+008$
 $M_{u2+} = 3.6072E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
 which is defined for the the static loading combination
 $M_{u2-} = 3.6072E+008$, 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:

u = 8.4581924E-005
Mu = 3.6072E+008

with full section properties:

b = 250.00
d = 457.00
d' = 43.00
v = 0.00136161
N = 4666.932
fc = 30.00
co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01290198$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01290198$

w_e ((5.4c), TBDY) = $ase * sh_{\min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.05524832$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.0541155
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), $ff_e = 882.7518$

fy = 0.09723711
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), $ff_e = 793.0837$

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) = 0.05494666

bo = 440.00

ho = 190.00

bi2 = 459400.00

$psh_{\min} = \text{Min}(psh_x, psh_y) = 0.00314159$

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) = 0.00314159

Ash = $A_{stir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 500.00

psh_y (5.4d) = 0.00628319

Ash = $A_{stir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 250.00

s = 100.00

$fy_{we} = 656.25$

fce = 30.00

From ((5.A5), TBDY), TBDY: $cc = 0.00294309$

c = confinement factor = 1.09431

y1 = 0.0025

sh1 = 0.008

ft1 = 787.50

fy1 = 656.25

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 787.50

fy2 = 656.25

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

yv = 0.0025

shv = 0.008

ftv = 787.50

fyv = 656.25

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.

with fsv = fs = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.15879823

2 = Asl,com/(b*d)*(fs2/fc) = 0.15879823

v = Asl,mid/(b*d)*(fsv/fc) = 0.07699308

and confined core properties:

b = 190.00

d = 427.00

d' = 13.00

fcc (5A.2, TBDY) = 32.82928

cc (5A.5, TBDY) = 0.00294309

c = confinement factor = 1.09431

1 = Asl,ten/(b*d)*(fs1/fc) = 0.22362502

2 = Asl,com/(b*d)*(fs2/fc) = 0.22362502

v = Asl,mid/(b*d)*(fsv/fc) = 0.10842425

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is not satisfied

--->

v < vs,c - RHS eq.(4.5) is satisfied

--->

su (4.8) = 0.17214129

Mu = MRc (4.15) = 3.6072E+008

u = su (4.1) = 8.4581924E-005

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_1

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 8.4581924E-005$

$\mu_1 = 3.6072E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00136161$

$N = 4666.932$

$f_c = 30.00$

α (5A.5, TBDY) = 0.002

Final value of μ_c : $\mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01290198$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.01290198$

μ_{we} ((5.4c), TBDY) = $\alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$

where $f = \alpha f_p * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.0541155$

$\alpha f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $pf = 2t_f/b_w = 0.004064$

$b_w = 500.00$

effective stress from (A.35), $f_{fe} = 882.7518$

$f_y = 0.09723711$

$\alpha f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $pf = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 793.0837$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \text{Cos}(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

αs_e ((5.4d), TBDY) = 0.05494666

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$

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) = 0.00314159

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 500.00$

$p_{sh,y}$ (5.4d) = 0.00628319

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 250.00$

$s = 100.00$
 $f_{ywe} = 656.25$
 $f_{ce} = 30.00$
 From ((5.A5), TBDY), TBDY: $cc = 0.00294309$
 $c = \text{confinement factor} = 1.09431$
 $y_1 = 0.0025$
 $sh_1 = 0.008$
 $ft_1 = 787.50$
 $fy_1 = 656.25$
 $su_1 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \text{min} = lb/ld = 1.00$
 $su_1 = 0.4 * esu_1 \text{nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu_1 \text{nominal} = 0.08$,
 For calculation of $esu_1 \text{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 656.25$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \text{min} = lb/lb, \text{min} = 1.00$
 $su_2 = 0.4 * esu_2 \text{nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu_2 \text{nominal} = 0.08$,
 For calculation of $esu_2 \text{nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 656.25$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $fy_v = 656.25$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \text{min} = lb/ld = 1.00$
 $suv = 0.4 * esuv \text{nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esuv \text{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv \text{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 656.25$
 with $Esv = Es = 200000.00$
 $1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.15879823$
 $2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.15879823$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.07699308$
 and confined core properties:
 $b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $fcc (5A.2, \text{TBDY}) = 32.82928$
 $cc (5A.5, \text{TBDY}) = 0.00294309$
 $c = \text{confinement factor} = 1.09431$
 $1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.22362502$
 $2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.22362502$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.10842425$$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

--->

$$s_u(4.8) = 0.17214129$$

$$M_u = M_{Rc}(4.15) = 3.6072E+008$$

$$u = s_u(4.1) = 8.4581924E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of M_{u2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 8.4581924E-005$$

$$M_u = 3.6072E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00136161$$

$$N = 4666.932$$

$$f_c = 30.00$$

$$\alpha(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \alpha: \alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01290198$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \alpha_c = 0.01290198$$

$$\alpha_{we}((5.4c), TBDY) = \alpha_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(\alpha_x, \alpha_y) = 0.05524832$$

where $\alpha = \alpha_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\alpha_x = 0.05411155$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$\alpha_y = 0.09723711$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 793.0837$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se}((5.4d), TBDY) = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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) = 0.00314159
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431

y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

yv = 0.0025
shv = 0.008
ftv = 787.50
fyv = 656.25
suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 656.25

with Esv = Es = 200000.00

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.15879823$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.15879823$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07699308$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 32.82928$$

$$c_c (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22362502$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.22362502$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.10842425$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

--->

$$s_u (4.8) = 0.17214129$$

$$\mu_u = M_{Rc} (4.15) = 3.6072E+008$$

$$u = s_u (4.1) = 8.4581924E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of μ_u

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 8.4581924E-005$$

$$\mu_u = 3.6072E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00136161$$

$$N = 4666.932$$

$$f_c = 30.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01290198$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01290198$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0541155$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$f_y = 0.09723711$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

effective stress from (A.35), $f_{f,e} = 793.0837$

$R = 40.00$

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} ((5.4d), TBDY) = 0.05494666$

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$

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)

$p_{sh,x} (5.4d) = 0.00314159$

$A_{sh} = A_{stir} \cdot n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 500.00$

$p_{sh,y} (5.4d) = 0.00628319$

$A_{sh} = A_{stir} \cdot n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 250.00$

$s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.00294309$

$c = \text{confinement factor} = 1.09431$

$y_1 = 0.0025$

$sh_1 = 0.008$

$ft_1 = 787.50$

$fy_1 = 656.25$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$su_1 = 0.4 \cdot esu_{1,nominal} ((5.5), TBDY) = 0.032$

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 $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$fy_2 = 656.25$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$fy_v = 656.25$

$suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $e_{suv_nominal} = 0.08$,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv_nominal}$ and γ_v , sh_v, ft_v, f_{y_v} , it is considered
characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

γ_1 , sh_1, ft_1, f_{y_1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 656.25$

with $E_{sv} = E_s = 200000.00$

1 = $Asl_{ten}/(b*d) * (f_{s1}/f_c) = 0.15879823$

2 = $Asl_{com}/(b*d) * (f_{s2}/f_c) = 0.15879823$

v = $Asl_{mid}/(b*d) * (f_{sv}/f_c) = 0.07699308$

and confined core properties:

b = 190.00

d = 427.00

d' = 13.00

f_{cc} (5A.2, TBDY) = 32.82928

cc (5A.5, TBDY) = 0.00294309

c = confinement factor = 1.09431

1 = $Asl_{ten}/(b*d) * (f_{s1}/f_c) = 0.22362502$

2 = $Asl_{com}/(b*d) * (f_{s2}/f_c) = 0.22362502$

v = $Asl_{mid}/(b*d) * (f_{sv}/f_c) = 0.10842425$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

s_u (4.8) = 0.17214129

$M_u = MR_c$ (4.15) = 3.6072E+008

u = s_u (4.1) = 8.4581924E-005

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 501229.73$

Calculation of Shear Strength at edge 1, $V_{r1} = 501229.73$

$V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Col0}$

$V_{Col0} = 501229.73$

$k_{nl} = 1$ (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)

$f_c' = 30.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 5.0983467E-013$

$V_u = 7.3955710E-032$

d = $0.8 * h = 400.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 329867.229$

$A_v = 157079.633$

$f_y = 525.00$

s = 100.00

V_s is multiplied by $Col = 1.00$

$$s/d = 0.25$$

$$V_f \text{ ((11-3)-(11.4), ACI 440) } = 240803.347$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$$w_f/s_f = 1 \text{ (FRP strips adjacent to one another).}$$

In (11.3) $\sin \theta + \cos \theta$ 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.

$$\text{orientation 1: } \theta = 45^\circ = 90.00$$

$$V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = NL * t / \text{NoDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440) } = 457.00$$

$$f_{fe} \text{ ((11-5), ACI 440) } = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 363854.192$$

$$b_w = 250.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 501229.73$

$$V_{r2} = V_{Col} \text{ ((10.3), ASCE 41-17) } = k_{nl} * V_{Col0}$$

$$V_{Col0} = 501229.73$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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).

$$= 1 \text{ (normal-weight concrete)}$$

$$f_c' = 30.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$\mu_u = 5.0983467E-013$$

$$\nu_u = 7.3955710E-032$$

$$d = 0.8 * h = 400.00$$

$$N_u = 4666.932$$

$$A_g = 125000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 329867.229$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

$$V_s \text{ is multiplied by } \phi_{Col} = 1.00$$

$$s/d = 0.25$$

$$V_f \text{ ((11-3)-(11.4), ACI 440) } = 240803.347$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$$w_f/s_f = 1 \text{ (FRP strips adjacent to one another).}$$

In (11.3) $\sin \theta + \cos \theta$ 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.

$$\text{orientation 1: } \theta = 45^\circ = 90.00$$

$$V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = NL * t / \text{NoDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440) } = 457.00$$

$$f_{fe} \text{ ((11-5), ACI 440) } = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 363854.192$$

$$b_w = 250.00$$

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, $\gamma = 0.85$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/l_d \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 3.8701821E-010$

Shear Force, $V_2 = -3021.16$

Shear Force, $V_3 = -1.0147380E-013$

Axial Force, $F = -4665.723$

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: $A_{st,mid} = 402.1239$

Mean Diameter of Tension Reinforcement, $DbL = 18.66667$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = 1.0^*$ $u = 0.05702691$

$u = y + p = 0.05702691$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00923029$ ((4.29), Biskinis Phd)

$M_y = 9.2818E+007$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 5.0279E+012$

factor = 0.30

Ag = 125000.00
fc' = 30.00
N = 4665.723
Ec*Ig = 1.6760E+013

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

y = Min(y_{ten} , y_{com})
 $y_{ten} = 1.8256820E-005$
with $f_y = 525.00$
d = 207.00
y = 0.30540153
A = 0.0199978
B = 0.01210998
with pt = 0.00801334
pc = 0.00801334
pv = 0.00388525
N = 4665.723
b = 500.00
" = 0.20772947
 $y_{comp} = 3.3724867E-005$
with $f_c^* (12.3, (ACI 440)) = 30.44529$
fc = 30.00
fl = 0.9425867
b = 500.00
h = 250.00
Ag = 125000.00
From (12.9), ACI 440: $k_a = 0.1506892$
g = pt + pc + pv = 0.01991193
rc = 40.00
Ae/Ac = 0.60275679
Effective FRP thickness, $t_f = NL*t*Cos(\theta_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
fu = 0.01
Ef = 64828.00
Ec = 25742.96
y = 0.30493938
A = 0.01980605
B = 0.01202411
with Es = 200000.00

Calculation of ratio lb/l_d

Adequate Lap Length: lb/l_d >= 1

- Calculation of ρ_p -

From table 10-8: $\rho_p = 0.04779662$

with:

- Columns controlled by inadequate development or splicing along the clear height because lb/l_d < 1

shear control ratio $V_y E / V_{Col} O E = 0.21712381$

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 = 4665.723

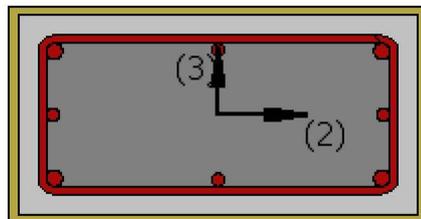
Ag = 125000.00

$f_{cE} = 30.00$
 $f_{yE} = f_{yIE} = 0.00$
 $\rho_l = \text{Area_Tot_Long_Rein}/(b*d) = 0.01991193$
 $b = 500.00$
 $d = 207.00$
 $f_{cE} = 30.00$

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 V_{Rd}
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, $\gamma = 0.85$
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 20.00$
New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 420.00$
Concrete Elasticity, $E_c = 25742.96$
Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of μ_y for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

New material: Concrete Strength, $f_c = f_{cm} = 30.00$

New material: Steel Strength, $f_s = f_{sm} = 525.00$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou,min} = l_b/l_d \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = 3.8701821E-010$

Shear Force, $V_a = -1.0147380E-013$

EDGE -B-

Bending Moment, $M_b = -8.2193294E-011$

Shear Force, $V_b = 1.0147380E-013$

BOTH EDGES

Axial Force, $F = -4665.723$

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: $A_{sl,mid} = 402.1239$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.66667$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0 \cdot V_n = 347902.508$

V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoI0} = 347902.508$

$V_{CoI} = 347902.508$

$k_n = 1.00$

displacement_ductility_demand = 0.00

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' 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)

$M/Vd = 2.00$

$M_u = 3.8701821E-010$

$V_u = 1.0147380E-013$

$d = 0.8 \cdot h = 200.00$

$N_u = 4665.723$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 131946.891$
 $A_v = 157079.633$
 $f_y = 420.00$
 $s = 100.00$
 V_s is multiplied by $Col = 1.00$
 $s/d = 0.50$
 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) $\sin + \cos$ 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, $tf1 = NL*t/NoDir = 1.016$
 $d_{fv} = d$ (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: $V_s + V_f \leq 297085.704$
 $b_w = 500.00$

 displacement ductility demand is calculated as δ / y

- Calculation of δ / y for END A -
 for rotation axis 2 and integ. section (a)

 From analysis, chord rotation $\theta = 2.8859901E-020$
 $y = (M_y * L_s / 3) / E_{eff} = 0.00923029$ ((4.29), Biskinis Phd)
 $M_y = 9.2818E+007$
 $L_s = M/V$ (with $L_s > 0.1*L$ and $L_s < 2*L$) = 1500.00
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 5.0279E+012$
 $\text{factor} = 0.30$
 $A_g = 125000.00$
 $f_c' = 30.00$
 $N = 4665.723$
 $E_c * I_g = 1.6760E+013$

 Calculation of Yielding Moment M_y

 Calculation of δ / y and M_y according to Annex 7 -

 $y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 1.8256820E-005$
 with $f_y = 525.00$
 $d = 207.00$
 $y = 0.30540153$
 $A = 0.0199978$
 $B = 0.01210998$
 with $pt = 0.00801334$
 $pc = 0.00801334$
 $pv = 0.00388525$
 $N = 4665.723$
 $b = 500.00$
 $\theta = 0.20772947$
 $y_{comp} = 3.3724867E-005$
 with $f_c' (12.3, (ACI 440)) = 30.44529$
 $f_c = 30.00$
 $f_l = 0.9425867$

$b = 500.00$
 $h = 250.00$
 $A_g = 125000.00$
 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, $t_f = NL * t * \cos(\theta) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 25742.96$
 $y = 0.30493938$
 $A = 0.01980605$
 $B = 0.01202411$
 with $E_s = 200000.00$

Calculation of ratio I_b/I_d

Adequate Lap Length: $I_b/I_d \geq 1$

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

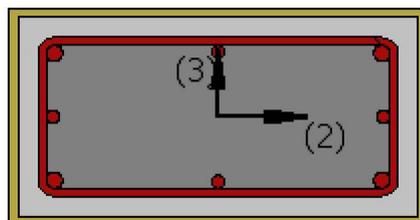
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_r)

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, $\gamma = 0.85$

Mean strength values are used for both shear and moment calculations.

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.09431

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou}, \min > = 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $bi = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = -1.0405794E-032$

EDGE -B-

Shear Force, $V_b = 1.0405794E-032$

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, $V_e/V_r = 0.21712381$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 88136.71$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.3221E+008$

$Mu_{1+} = 1.3221E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction

which is defined for the static loading combination

$Mu1- = 1.3221E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$Mpr2 = \text{Max}(Mu2+, Mu2-) = 1.3221E+008$

$Mu2+ = 1.3221E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$Mu2- = 1.3221E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of $Mu1+$

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$u = 0.0002015$

$Mu = 1.3221E+008$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00150304$

$N = 4666.932$

$f_c = 30.00$

$\alpha_{co} (5A.5, TBDY) = 0.002$

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01290198$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01290198$

$\phi_{we} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.05524832$

where $\phi = \alpha_f * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\phi_x = 0.0541155$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{f,e} = 882.7518$

$\phi_y = 0.09723711$

$\alpha_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{f,e} = 793.0837$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\alpha_{se} ((5.4d), TBDY) = 0.05494666$

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$\rho_{sh,min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.00314159$

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)

 $\rho_{sh,x} (5.4d) = 0.00314159$

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 500.00$

$\rho_{sh,y} (5.4d) = 0.00628319$

Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00

From ((5.A.5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431

y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

yv = 0.0025
shv = 0.008
ftv = 787.50
fyv = 656.25
suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17529176

2 = Asl,com/(b*d)*(fs2/fc) = 0.17529176

v = Asl,mid/(b*d)*(fsv/fc) = 0.08498995

and confined core properties:

b = 440.00
d = 177.00
d' = 13.00

fcc (5A.2, TBDY) = 32.82928

cc (5A.5, TBDY) = 0.00294309

c = confinement factor = 1.09431

1 = $Asl_{ten}/(b*d)*(fs1/fc) = 0.23295708$

2 = $Asl_{com}/(b*d)*(fs2/fc) = 0.23295708$

v = $Asl_{mid}/(b*d)*(fsv/fc) = 0.11294889$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

v < $v_{s,y2}$ - LHS eq.(4.5) is satisfied

su (4.9) = 0.23279566

Mu = MRc (4.14) = 1.3221E+008

u = su (4.1) = 0.0002015

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Mu1-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 0.0002015

Mu = 1.3221E+008

with full section properties:

b = 500.00

d = 207.00

d' = 43.00

v = 0.00150304

N = 4666.932

fc = 30.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = shear_factor * Max(cu, cc) = 0.01290198$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01290198$

we ((5.4c), TBDY) = $ase * sh_{,min} * fy_{we}/f_{ce} + Min(f_x, f_y) = 0.05524832$

where $f = af * pf * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.0541155

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), $ff_e = 882.7518$

fy = 0.09723711

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), $ff_e = 793.0837$

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) = 0.05494666

bo = 440.00

ho = 190.00

bi2 = 459400.00

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00314159$$

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)

$$psh,x (5.4d) = 0.00314159$$

$$Ash = Astir*ns = 78.53982$$

$$\text{No stirrups, } ns = 2.00$$

$$bk = 500.00$$

$$psh,y (5.4d) = 0.00628319$$

$$Ash = Astir*ns = 78.53982$$

$$\text{No stirrups, } ns = 2.00$$

$$bk = 250.00$$

$$s = 100.00$$

$$fywe = 656.25$$

$$fce = 30.00$$

From ((5.A5), TBDY), TBDY: $cc = 0.00294309$

$$c = \text{confinement factor} = 1.09431$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 787.50$$

$$fy1 = 656.25$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/l_d = 1.00$$

$$su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
characteristic value $fsy1 = fs/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 656.25$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.0025$$

$$sh2 = 0.008$$

$$ft2 = 787.50$$

$$fy2 = 656.25$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/l_b,min = 1.00$$

$$su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
characteristic value $fsy2 = fs/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 656.25$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.0025$$

$$shv = 0.008$$

$$ftv = 787.50$$

$$fyv = 656.25$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/l_d = 1.00$$

$$suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_nominal$ and 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.

$$\text{with } fsv = fs = 656.25$$

with $E_{sv} = E_s = 200000.00$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.17529176$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.17529176$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08498995$$

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 32.82928$$

$$c_c (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.23295708$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.23295708$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.11294889$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.23279566$$

$$M_u = M_{Rc} (4.14) = 1.3221E+008$$

$$u = s_u (4.1) = 0.0002015$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of M_{u2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 0.0002015$$

$$M_u = 1.3221E+008$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00150304$$

$$N = 4666.932$$

$$f_c = 30.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01290198$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01290198$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.05411155$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$f_y = 0.09723711$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 793.0837$$

R = 40.00
Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase((5.4d), TBDY) = 0.05494666$
 $bo = 440.00$
 $ho = 190.00$
 $bi2 = 459400.00$
 $psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00314159$

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)

$psh_{,x}(5.4d) = 0.00314159$
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $bk = 500.00$

$psh_{,y}(5.4d) = 0.00628319$
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $bk = 250.00$

$s = 100.00$
 $f_{ywe} = 656.25$
 $f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00294309$
 $c = \text{confinement factor} = 1.09431$

$y_1 = 0.0025$
 $sh_1 = 0.008$
 $ft_1 = 787.50$
 $fy_1 = 656.25$
 $su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou_{,min} = lb/ld = 1.00$

$su_1 = 0.4 \cdot esu1_{nominal}((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou_{,min} = lb/lb_{,min} = 1.00$

$su_2 = 0.4 \cdot esu2_{nominal}((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $fy_v = 656.25$
 $suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lo_{u,min} = lb/d = 1.00

su_v = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value f_{sv} = f_{sv}/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and γ_v, sh_v,ft_v,fy_v, it is considered characteristic value f_{sv} = f_{sv}/1.2, from table 5.1, TBDY.

γ₁, sh₁,ft₁,fy₁, are also multiplied by Min(1,1.25*(lb/d)^{2/3}), from 10.3.5, ASCE41-17.

with f_{sv} = f_s = 656.25

with E_{sv} = E_s = 200000.00

1 = Asl_{ten}/(b*d)*(f_{s1}/f_c) = 0.17529176

2 = Asl_{com}/(b*d)*(f_{s2}/f_c) = 0.17529176

v = Asl_{mid}/(b*d)*(f_{sv}/f_c) = 0.08498995

and confined core properties:

b = 440.00

d = 177.00

d' = 13.00

f_{cc} (5A.2, TBDY) = 32.82928

cc (5A.5, TBDY) = 0.00294309

c = confinement factor = 1.09431

1 = Asl_{ten}/(b*d)*(f_{s1}/f_c) = 0.23295708

2 = Asl_{com}/(b*d)*(f_{s2}/f_c) = 0.23295708

v = Asl_{mid}/(b*d)*(f_{sv}/f_c) = 0.11294889

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

v < v_{s,y2} - LHS eq.(4.5) is satisfied

su (4.9) = 0.23279566

Mu = MRc (4.14) = 1.3221E+008

u = su (4.1) = 0.0002015

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu₂-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 0.0002015

Mu = 1.3221E+008

with full section properties:

b = 500.00

d = 207.00

d' = 43.00

v = 0.00150304

N = 4666.932

f_c = 30.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01290198

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01290198

we ((5.4c), TBDY) = ase* sh_{min}*fy_{we}/f_{ce}+Min(f_x, f_y) = 0.05524832

where f = af*pf*ffe/f_{ce} is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

f_x = 0.0541155

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), $f_{f,e} = 882.7518$

fy = 0.09723711
af = 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), $f_{f,e} = 793.0837$

R = 40.00
Effective FRP thickness, $t_f = NL*t*Cos(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.05494666
bo = 440.00
ho = 190.00
bi2 = 459400.00

psh,min = Min(psh,x , psh,y) = 0.00314159
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) = 0.00314159
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431

y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value $f_{s1} = f_s/1.2$, 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 $f_{s1} = f_s = 656.25$

with $E_{s1} = E_s = 200000.00$

y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered

characteristic value $f_{s2} = f_s/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s2} = f_s = 656.25$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$f_{yv} = 656.25$

$s_{uv} = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/d = 1.00$

$s_{uv} = 0.4 \cdot e_{suv,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv,nominal}$ and y_v, sh_v, ft_v, f_{yv} , it is considered

characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 656.25$

with $E_{sv} = E_s = 200000.00$

1 = $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.17529176$

2 = $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.17529176$

v = $A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08498995$

and confined core properties:

b = 440.00

d = 177.00

d' = 13.00

f_{cc} (5A.2, TBDY) = 32.82928

cc (5A.5, TBDY) = 0.00294309

c = confinement factor = 1.09431

1 = $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.23295708$

2 = $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.23295708$

v = $A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.11294889$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < v_{s,y2} - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.23279566

Mu = MRc (4.14) = 1.3221E+008

u = su (4.1) = 0.0002015

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 405928.36$

Calculation of Shear Strength at edge 1, $V_{r1} = 405928.36$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} \cdot V_{Col0}$

$V_{Col0} = 405928.36$

$k_{nl} = 1$ (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)

$f_c' = 30.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 4.7466732E-012$

$V_u = 1.0405794E-032$

d = $0.8 \cdot h = 200.00$

$N_u = 4666.932$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 164933.614$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.50$
 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) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $tf_1 = NL * t / \text{NoDir} = 1.016$
 $df_v = d$ (figure 11.2, ACI 440) = 207.00
 ff_e ((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: $V_s + V_f \leq 363854.192$
 $bw = 500.00$

 Calculation of Shear Strength at edge 2, $V_{r2} = 405928.36$
 $V_{r2} = V_{\text{Col}}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{\text{Col}0}$
 $V_{\text{Col}0} = 405928.36$
 $k_{nl} = 1$ (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).

 $\beta = 1$ (normal-weight concrete)
 $f_c' = 30.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 4.7466732E-012$
 $V_u = 1.0405794E-032$
 $d = 0.8 * h = 200.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 164933.614$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.50$
 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) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $tf_1 = NL * t / \text{NoDir} = 1.016$
 $df_v = d$ (figure 11.2, ACI 440) = 207.00
 ff_e ((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: $V_s + V_f \leq 363854.192$
 $bw = 500.00$

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, $\gamma = 0.85$
Mean strength values are used for both shear and moment calculations.
Consequently:
New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$
Concrete Elasticity, $E_c = 25742.96$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
New material: Steel Strength, $f_s = 1.25 * f_{sm} = 656.25$

Section Height, $H = 250.00$
Section Width, $W = 500.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.09431
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou}, \min >= 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
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, $V_a = -7.3955710E-032$
EDGE -B-
Shear Force, $V_b = 7.3955710E-032$
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 , $V_e/V_r = 0.47977838$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 240479.187$

with
 $M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 3.6072E+008$
 $M_{u1+} = 3.6072E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $M_{u1-} = 3.6072E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 3.6072E+008$
 $M_{u2+} = 3.6072E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination
 $M_{u2-} = 3.6072E+008$, 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:

$\phi_u = 8.4581924E-005$

$M_u = 3.6072E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00136161$

$N = 4666.932$

$f_c = 30.00$

α_{co} (5A.5, TBDY) = 0.002

Final value of ϕ_{cu} : $\phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01290198$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_{cu} = 0.01290198$

ω_{ve} ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$

where $f = \alpha_f * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.0541155$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{f,e} = 882.7518$

$f_y = 0.09723711$

$\alpha_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{f,e} = 793.0837$

$R = 40.00$

Effective FRP thickness, $t_f = N L * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

α_{se} ((5.4d), TBDY) = 0.05494666

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$\text{psh}_{, \text{min}} = \text{Min}(\text{psh}_{,x}, \text{psh}_{,y}) = 0.00314159$

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) = 0.00314159
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431

y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (\text{lb}/\text{d})^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (\text{lb}/\text{d})^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

yv = 0.0025
shv = 0.008
ftv = 787.50
fyv = 656.25
suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (\text{lb}/\text{d})^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 656.25

with Esv = Es = 200000.00

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.15879823$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.15879823$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07699308$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 32.82928$$

$$c_c (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22362502$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.22362502$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.10842425$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

--->

$$s_u (4.8) = 0.17214129$$

$$\mu_u = M_{Rc} (4.15) = 3.6072E+008$$

$$u = s_u (4.1) = 8.4581924E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of μ_{u1} -

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 8.4581924E-005$$

$$\mu_u = 3.6072E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00136161$$

$$N = 4666.932$$

$$f_c = 30.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01290198$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01290198$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0541155$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$f_y = 0.09723711$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

effective stress from (A.35), $f_{f,e} = 793.0837$

R = 40.00

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se}((5.4d), TBDY) = 0.05494666$

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$

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)

$p_{sh,x} (5.4d) = 0.00314159$

$A_{sh} = A_{stir} \cdot n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 500.00$

$p_{sh,y} (5.4d) = 0.00628319$

$A_{sh} = A_{stir} \cdot n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 250.00$

$s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.00294309$

$c = \text{confinement factor} = 1.09431$

$y_1 = 0.0025$

$sh_1 = 0.008$

$ft_1 = 787.50$

$fy_1 = 656.25$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$su_1 = 0.4 \cdot esu_{1,nominal}((5.5), TBDY) = 0.032$

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 $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$fy_2 = 656.25$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 \cdot esu_{2,nominal}((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$fy_v = 656.25$

$suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_0/l_{0,min} = l_b/l_d = 1.00$

$s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv,nominal}$ and γ_v , sh_v, f_{tv}, f_{yv} , it is considered
characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.

γ_1 , sh_1, f_{t1}, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 656.25$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.15879823$

$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.15879823$

$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.07699308$

and confined core properties:

$b = 190.00$

$d = 427.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 32.82928$

$cc (5A.5, TBDY) = 0.00294309$

$c =$ confinement factor = 1.09431

$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.22362502$

$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.22362502$

$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.10842425$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

$s_u (4.8) = 0.17214129$

$M_u = M_{Rc} (4.15) = 3.6072E+008$

$u = s_u (4.1) = 8.4581924E-005$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of M_{u2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 8.4581924E-005$

$M_u = 3.6072E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00136161$

$N = 4666.932$

$f_c = 30.00$

$co (5A.5, TBDY) = 0.002$

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, cc) = 0.01290198$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.01290198$

$w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.0541155$

$a_f = 0.45253333$

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), $ff,e = 882.7518$

fy = 0.09723711
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), $ff,e = 793.0837$

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) = 0.05494666
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.00314159
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) = 0.00314159
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00
From ((5.A5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431
y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 1.00
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by $Min(1,1.25*(lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs1 = fs = 656.25$
with $Es1 = Es = 200000.00$
y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00

$$su_2 = 0.4 * esu_{2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{2_nominal} = 0.08$,

For calculation of $esu_{2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$fy_v = 656.25$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$lo/lo_{u,min} = lb/ld = 1.00$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $fsv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered characteristic value $fsv = fsv/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fsv = fs = 656.25$

with $Es_v = Es = 200000.00$

$$1 = Asl_{ten}/(b*d)*(fs_1/fc) = 0.15879823$$

$$2 = Asl_{com}/(b*d)*(fs_2/fc) = 0.15879823$$

$$v = Asl_{mid}/(b*d)*(fsv/fc) = 0.07699308$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 32.82928$$

$$cc (5A.5, TBDY) = 0.00294309$$

$c = \text{confinement factor} = 1.09431$

$$1 = Asl_{ten}/(b*d)*(fs_1/fc) = 0.22362502$$

$$2 = Asl_{com}/(b*d)*(fs_2/fc) = 0.22362502$$

$$v = Asl_{mid}/(b*d)*(fsv/fc) = 0.10842425$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

--->

$$su (4.8) = 0.17214129$$

$$Mu = MRc (4.15) = 3.6072E+008$$

$$u = su (4.1) = 8.4581924E-005$$

Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of Mu_2 -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 8.4581924E-005$$

$$Mu = 3.6072E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00136161$$

$$N = 4666.932$$

$$fc = 30.00$$

$$co \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01290198$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.01290198$$

$$\text{we ((5.4c), TBDY)} = ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.05524832$$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$fx = 0.0541155$$

$$af = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } ff,e = 882.7518$$

$$fy = 0.09723711$$

$$af = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff,e = 793.0837$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } tf = NL * t * \text{Cos}(b1) = 1.016$$

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = 0.05494666$$

$$bo = 440.00$$

$$ho = 190.00$$

$$bi2 = 459400.00$$

$$psh_{min} = \text{Min}(psh,x, psh,y) = 0.00314159$$

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)

$$psh,x \text{ (5.4d)} = 0.00314159$$

$$Ash = Astir * ns = 78.53982$$

$$\text{No stirrups, } ns = 2.00$$

$$bk = 500.00$$

$$psh,y \text{ (5.4d)} = 0.00628319$$

$$Ash = Astir * ns = 78.53982$$

$$\text{No stirrups, } ns = 2.00$$

$$bk = 250.00$$

$$s = 100.00$$

$$fy_{we} = 656.25$$

$$f_{ce} = 30.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 787.50$$

$$fy1 = 656.25$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou_{min} = lb/ld = 1.00$$

$$su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_{nominal} = 0.08,$$

For calculation of esu1_nominal and y1, sh1, ft1, fy1, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$fy_2 = 656.25$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$fy_v = 656.25$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$su_v = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fsv = fs = 656.25$

with $Esv = Es = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.15879823$

$2 = A_{sl,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.15879823$

$v = A_{sl,mid}/(b \cdot d) \cdot (fsv/f_c) = 0.07699308$

and confined core properties:

$b = 190.00$

$d = 427.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 32.82928$

$cc (5A.5, TBDY) = 0.00294309$

$c = \text{confinement factor} = 1.09431$

$1 = A_{sl,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.22362502$

$2 = A_{sl,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.22362502$

$v = A_{sl,mid}/(b \cdot d) \cdot (fsv/f_c) = 0.10842425$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

--->

$su (4.8) = 0.17214129$

$Mu = MRc (4.15) = 3.6072E+008$

$u = su (4.1) = 8.4581924E-005$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 501229.73$

Calculation of Shear Strength at edge 1, $V_{r1} = 501229.73$

$V_{r1} = V_{Co1} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Co10}$

$V_{Co10} = 501229.73$

$k_{nl} = 1$ (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)

$f_c' = 30.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / V d = 2.00$

$\mu_u = 5.0983467E-013$

$\nu_u = 7.3955710E-032$

$d = 0.8 * h = 400.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 329867.229$

$A_v = 157079.633$

$f_y = 525.00$

$s = 100.00$

V_s is multiplied by $Col = 1.00$

$s / d = 0.25$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 240803.347$

$f = 0.95$, for fully-wrapped sections

$w_f / s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \csc) \sin \alpha$ which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\alpha_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 457.00

$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 363854.192$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 501229.73$

$V_{r2} = V_{Co2} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Co10}$

$V_{Co10} = 501229.73$

$k_{nl} = 1$ (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)

$f_c' = 30.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / V d = 2.00$

$\mu_u = 5.0983467E-013$

$\nu_u = 7.3955710E-032$

$d = 0.8 * h = 400.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 329867.229$

$A_v = 157079.633$

$f_y = 525.00$

$s = 100.00$

V_s is multiplied by $Col = 1.00$

$s / d = 0.25$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 240803.347$

$f = 0.95$, 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 a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL * t / \text{NoDir} = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 457.00
 ffe ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 363854.192$
 $bw = 250.00$

 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, $\gamma = 0.85$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$
 Concrete Elasticity, $E_c = 25742.96$
 Steel Elasticity, $E_s = 200000.00$
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_b/l_d > 1$)
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $ff_u = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $ef_u = 0.01$
 Number of directions, $\text{NoDir} = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

 Bending Moment, $M = -9.0652E+006$
 Shear Force, $V_2 = -3021.16$
 Shear Force, $V_3 = -1.0147380E-013$

Axial Force, $F = -4665.723$
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, $Db_L = 18.66667$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = 1.0^*$ $u = 0.06476803$
 $u = y + p = 0.06476803$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.01029579$ ((4.29), Biskinis Phd))
 $M_y = 2.0703E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3000.571
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 2.0112E+013$
factor = 0.30
 $A_g = 125000.00$
 $f_c' = 30.00$
 $N = 4665.723$
 $E_c * I_g = 6.7039E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 7.9424748E-006$
with $f_y = 525.00$
 $d = 457.00$
 $y = 0.27680192$
 $A = 0.01811617$
 $B = 0.00994561$
with $pt = 0.00725935$
 $pc = 0.00725935$
 $p_v = 0.00351968$
 $N = 4665.723$
 $b = 250.00$
 $" = 0.0940919$
 $y_{comp} = 1.6862744E-005$
with $f_c^* (12.3, (ACI 440)) = 30.44585$
 $f_c = 30.00$
 $f_l = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $A_g = 125000.00$
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, $t_f = NL * t * \text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 25742.96$
 $y = 0.27624705$
 $A = 0.01794246$
 $B = 0.00986782$

with $E_s = 200000.00$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

- Calculation of ρ -

From table 10-8: $\rho = 0.05447223$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$
shear control ratio $V_{yE}/V_{ColOE} = 0.47977838$

$d = 457.00$

$s = 0.00$

$t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.00$

$A_v = 157.0796$, 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.

$NUD = 4665.723$

$A_g = 125000.00$

$f_{cE} = 30.00$

$f_{ytE} = f_{ylE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein}/(b*d) = 0.01803838$

$b = 250.00$

$d = 457.00$

$f_{cE} = 30.00$

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

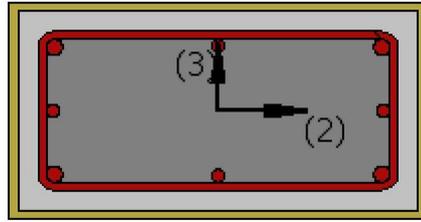
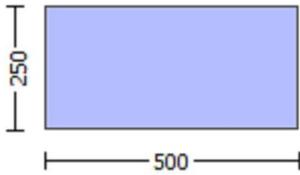
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

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, $\gamma = 0.85$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 20.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 420.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

New material: Concrete Strength, $f_c = f_{cm} = 30.00$

New material: Steel Strength, $f_s = f_{sm} = 525.00$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou, \min} = l_b/l_d \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -9.0652E+006$

Shear Force, $V_a = -3021.16$

EDGE -B-

Bending Moment, $M_b = -0.00051461$

Shear Force, $V_b = 3021.16$
 BOTH EDGES
 Axial Force, $F = -4665.723$
 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: $A_{st,mid} = 402.1239$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.66667$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0 \cdot V_n = 409422.112$
 V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoL} = 409422.112$
 $V_{CoL} = 409422.112$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.06567488$

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)
 $M/Vd = 2.00$
 $\mu_u = 0.00051461$
 $V_u = 3021.16$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4665.723$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 263893.783$
 $A_v = 157079.633$
 $f_y = 420.00$
 $s = 100.00$
 V_s is multiplied by $Col = 1.00$
 $s/d = 0.25$
 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 $V_f(a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $a_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (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: $V_s + V_f \leq 297085.704$
 $b_w = 250.00$

$displacement_ductility_demand$ is calculated as δ / y

- Calculation of δ / y for END B -
 for rotation axis 3 and integ. section (b)

From analysis, chord rotation $\theta = 6.7604620E-005$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00102938$ ((4.29), Biskinis Phd)
 $M_y = 2.0703E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 2.0112E+013$

factor = 0.30

$A_g = 125000.00$

$f_c' = 30.00$

$N = 4665.723$

$E_c * I_g = 6.7039E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 7.9424748E-006$

with $f_y = 525.00$

$d = 457.00$

$y = 0.27680192$

$A = 0.01811617$

$B = 0.00994561$

with $p_t = 0.00725935$

$p_c = 0.00725935$

$p_v = 0.00351968$

$N = 4665.723$

$b = 250.00$

" = 0.0940919

$y_{comp} = 1.6862744E-005$

with f_c^* (12.3, (ACI 440)) = 30.44585

$f_c = 30.00$

$f_l = 0.9425867$

$b = 250.00$

$h = 500.00$

$A_g = 125000.00$

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, $t_f = N L * t * \text{Cos}(b_1) = 1.016$

effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 25742.96$

$y = 0.27624705$

$A = 0.01794246$

$B = 0.00986782$

with $E_s = 200000.00$

Calculation of ratio I_b/I_d

Adequate Lap Length: $I_b/I_d \geq 1$

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

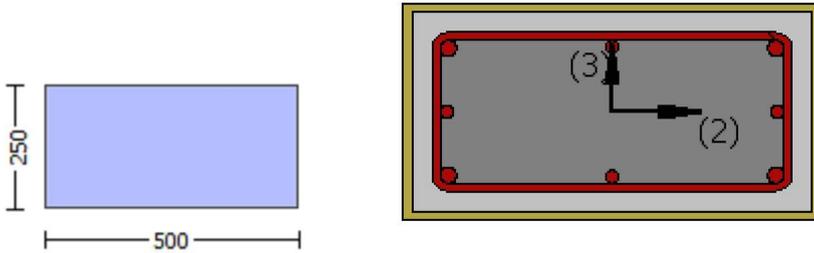
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_u)

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, $\gamma = 0.85$

Mean strength values are used for both shear and moment calculations.

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.09431

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou, \min} \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $bi = 0.00^\circ$

Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, Va = -1.0405794E-032
EDGE -B-
Shear Force, Vb = 1.0405794E-032
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 , $V_e/V_r = 0.21712381$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 88136.71$
with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 1.3221E+008$
 $\mu_{u1+} = 1.3221E+008$, 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
 $\mu_{u1-} = 1.3221E+008$, 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
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 1.3221E+008$
 $\mu_{u2+} = 1.3221E+008$, 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
 $\mu_{u2-} = 1.3221E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of μ_{u1+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:
 $\mu_u = 0.0002015$
 $\mu_u = 1.3221E+008$

with full section properties:

$b = 500.00$
 $d = 207.00$
 $d' = 43.00$
 $v = 0.00150304$
 $N = 4666.932$
 $f_c = 30.00$
 α_1 (5A.5, TBDY) = 0.002
Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.01290198$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\mu_u = 0.01290198$
 μ_u ((5.4c), TBDY) = $\alpha_1 * \rho_{s,min} * f_{y,we} / f_{c,e} + \text{Min}(f_x, f_y) = 0.05524832$
where $f = \alpha_1 * \rho_{f,frp} * f_{f,e} / f_{c,e}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.0541155$
 $\alpha_1 = 0.45253333$
 $b = 500.00$
 $h = 250.00$
From EC8 A.4.4.3(6), $\rho_{f,frp} = 2t_f/bw = 0.004064$

bw = 500.00
effective stress from (A.35), $f_{f,e} = 882.7518$

fy = 0.09723711
af = 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), $f_{f,e} = 793.0837$

R = 40.00
Effective FRP thickness, $t_f = NL*t*Cos(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.05494666
bo = 440.00
ho = 190.00
bi2 = 459400.00

psh,min = Min(psh,x , psh,y) = 0.00314159
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) = 0.00314159
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00
From ((5.A5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431

y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value $f_{s1} = f_s/1.2$, 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 $f_{s1} = f_s = 656.25$

with $E_{s1} = E_s = 200000.00$

y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered

characteristic value $f_{s2} = f_s/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s2} = f_s = 656.25$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$f_{yv} = 656.25$

$s_{uv} = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/d = 1.00$

$s_{uv} = 0.4 \cdot e_{suv,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv,nominal}$ and y_v, sh_v, ft_v, f_{yv} , it is considered

characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 656.25$

with $E_{sv} = E_s = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.17529176$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.17529176$

v = $As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08498995$

and confined core properties:

b = 440.00

d = 177.00

d' = 13.00

f_{cc} (5A.2, TBDY) = 32.82928

cc (5A.5, TBDY) = 0.00294309

c = confinement factor = 1.09431

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.23295708$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.23295708$

v = $As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.11294889$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < v_{s,y2} - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.23279566

Mu = MRc (4.14) = 1.3221E+008

u = su (4.1) = 0.0002015

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Mu1-

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

u = 0.0002015

Mu = 1.3221E+008

with full section properties:

b = 500.00

d = 207.00

d' = 43.00

v = 0.00150304

N = 4666.932

f_c = 30.00

co (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} \cdot \text{Max}(\phi_u, \phi_c) = 0.01290198$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.01290198$

w_e ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.0541155$

$af = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $ff_e = 882.7518$

 $f_y = 0.09723711$

$af = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff_e = 793.0837$

 $R = 40.00$

Effective FRP thickness, $tf = NL * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

ase ((5.4d), TBDY) = 0.05494666

$bo = 440.00$

$ho = 190.00$

$bi_2 = 459400.00$

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00314159$

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) = 0.00314159

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$bk = 500.00$

 psh_y (5.4d) = 0.00628319

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$bk = 250.00$

 $s = 100.00$

$fy_{we} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00294309$

$c =$ confinement factor = 1.09431

$y_1 = 0.0025$

$sh_1 = 0.008$

$ft_1 = 787.50$

$fy_1 = 656.25$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{u,min} = lb/ld = 1.00$

$su_1 = 0.4 * esu_{1,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1 / 1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$$ft2 = 787.50$$

$$fy2 = 656.25$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 1.00$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 656.25$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.0025$$

$$shv = 0.008$$

$$ftv = 787.50$$

$$fyv = 656.25$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 1.00$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 656.25$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.17529176$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.17529176$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.08498995$$

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 32.82928$$

$$cc (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.23295708$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.23295708$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.11294889$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

v < vs,y2 - LHS eq.(4.5) is satisfied

---->

$$su (4.9) = 0.23279566$$

$$Mu = MRc (4.14) = 1.3221E+008$$

$$u = su (4.1) = 0.0002015$$

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Mu2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 0.0002015$$

$$Mu = 1.3221E+008$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00150304$$

$$N = 4666.932$$

$$f_c = 30.00$$

$$\alpha (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \alpha: \alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01290198$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \alpha_c = 0.01290198$$

$$\omega_e ((5.4c), \text{TBDY}) = \alpha^* \cdot \text{sh}_{\min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$$

where $f = \alpha^* \cdot \rho_f \cdot f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0541155$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 882.7518$$

$$f_y = 0.09723711$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 793.0837$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} ((5.4d), \text{TBDY}) = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$\rho_{sh,\min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.00314159$$

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)

$$\rho_{sh,x} (5.4d) = 0.00314159$$

$$A_{sh} = A_{stir} \cdot n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$\rho_{sh,y} (5.4d) = 0.00628319$$

$$A_{sh} = A_{stir} \cdot n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 30.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \alpha_c = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$f_{t1} = 787.50$$

$$f_{y1} = 656.25$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 1.00$$

$$s_u1 = 0.4 * e_{s1_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s1_nominal} = 0.08$,

For calculation of $e_{s1_nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $f_{sy1} = f_s/1.2$, 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.

$$\text{with } f_{s1} = f_s = 656.25$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.0025$$

$$sh_2 = 0.008$$

$$ft_2 = 787.50$$

$$fy_2 = 656.25$$

$$s_u2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$$

$$s_u2 = 0.4 * e_{s2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s2_nominal} = 0.08$,

For calculation of $e_{s2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $f_{sy2} = f_s/1.2$, 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.

$$\text{with } f_{s2} = f_s = 656.25$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$fy_v = 656.25$$

$$s_{u,v} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 1.00$$

$$s_{u,v} = 0.4 * e_{s_{u,v}_nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } f_{sv} = f_s = 656.25$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.17529176$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.17529176$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.08498995$$

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 32.82928$$

$$cc (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.23295708$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.23295708$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.11294889$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.23279566$$

$$\mu = M_{Rc} (4.14) = 1.3221E+008$$

$$u = s_u (4.1) = 0.0002015$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Mu2-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 0.0002015$$

$$Mu = 1.3221E+008$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00150304$$

$$N = 4666.932$$

$$f_c = 30.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01290198$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01290198$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0541155$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$f_y = 0.09723711$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 793.0837$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.00314159$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00628319$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 30.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00294309$
 $c = \text{confinement factor} = 1.09431$

$y1 = 0.0025$
 $sh1 = 0.008$
 $ft1 = 787.50$
 $fy1 = 656.25$
 $su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou,min = lb/d = 1.00$

$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 656.25$

with $Es1 = Es = 200000.00$

$y2 = 0.0025$
 $sh2 = 0.008$
 $ft2 = 787.50$
 $fy2 = 656.25$
 $su2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou,min = lb/lb,min = 1.00$

$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 656.25$

with $Es2 = Es = 200000.00$

$yv = 0.0025$
 $shv = 0.008$
 $ftv = 787.50$
 $fyv = 656.25$
 $suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou,min = lb/d = 1.00$

$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fsv = fs = 656.25$

with $Esv = Es = 200000.00$

$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.17529176$

$2 = Asl,com / (b * d) * (fs2 / fc) = 0.17529176$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.08498995$

and confined core properties:

$b = 440.00$

$d = 177.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 32.82928$

$cc (5A.5, TBDY) = 0.00294309$

$c = \text{confinement factor} = 1.09431$

$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.23295708$

$2 = Asl,com / (b * d) * (fs2 / fc) = 0.23295708$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.11294889$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_s, y_2$ - LHS eq.(4.5) is satisfied

--->

$$\mu_u(4.9) = 0.23279566$$

$$\mu_u = M_{Rc}(4.14) = 1.3221E+008$$

$$u = \mu_u(4.1) = 0.0002015$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 405928.36$

Calculation of Shear Strength at edge 1, $V_{r1} = 405928.36$

$$V_{r1} = V_{Col}((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$$

$$V_{Col0} = 405928.36$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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).

$$= 1 \text{ (normal-weight concrete)}$$

$$f_c' = 30.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$\mu_u = 4.7466732E-012$$

$$V_u = 1.0405794E-032$$

$$d = 0.8 * h = 200.00$$

$$N_u = 4666.932$$

$$A_g = 125000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 164933.614$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

$$V_s \text{ is multiplied by } \text{Col} = 1.00$$

$$s/d = 0.50$$

$$V_f \text{ ((11-3)-(11.4), ACI 440) } = 109072.851$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$$w_f/s_f = 1 \text{ (FRP strips adjacent to one another).}$$

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \theta$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a_i)$, 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.

$$\text{orientation 1: } \theta = b_1 + 90^\circ = 90.00$$

$$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = N_L * t / N_{oDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440) } = 207.00$$

$$f_{fe} \text{ ((11-5), ACI 440) } = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 363854.192$$

$$b_w = 500.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 405928.36$

$$V_{r2} = V_{Col}((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$$

$$V_{Col0} = 405928.36$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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).

$$= 1 \text{ (normal-weight concrete)}$$

$$f_c' = 30.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$M/Vd = 2.00$
 $\mu_u = 4.7466732E-012$
 $\mu_v = 1.0405794E-032$
 $d = 0.8 \cdot h = 200.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 164933.614$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.50$
 $V_f ((11-3)-(11.4), \text{ACI 440}) = 109072.851$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ 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 $V_f(\theta, a_i)$, 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: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 207.00
 $f_{fe} ((11-5), \text{ACI 440}) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 363854.192$
 $b_w = 500.00$

 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, $\phi = 0.85$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$
 Concrete Elasticity, $E_c = 25742.96$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 656.25$
 #####
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.09431
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{ou}, \text{min} \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = -7.3955710E-032$

EDGE -B-

Shear Force, $V_b = 7.3955710E-032$

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, $V_e/V_r = 0.47977838$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 240479.187$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 3.6072E+008$

$M_{u1+} = 3.6072E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 3.6072E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 3.6072E+008$

$M_{u2+} = 3.6072E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 3.6072E+008$, 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:

$\phi_u = 8.4581924E-005$

$M_u = 3.6072E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00136161$

$N = 4666.932$

$f_c = 30.00$

$\omega (5A.5, \text{TBDY}) = 0.002$

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01290198$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.01290198$

w_e ((5.4c), TBDY) = $ase * sh_{min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.0541155$

$af = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{f,e} = 882.7518$

 $f_y = 0.09723711$

$af = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{f,e} = 793.0837$

 $R = 40.00$

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) = 0.05494666

$b_o = 440.00$

$h_o = 190.00$

$bi2 = 459400.00$

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00314159$

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) = 0.00314159

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 500.00$

 psh_y (5.4d) = 0.00628319

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 250.00$

 $s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00294309$

$c =$ confinement factor = 1.09431

$y_1 = 0.0025$

$sh_1 = 0.008$

$ft_1 = 787.50$

$fy_1 = 656.25$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{min} = lb/ld = 1.00$

$su_1 = 0.4 * esu_{1_nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{1_nominal} = 0.08$,

For calculation of $esu_{1_nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1 / 1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$$f_y2 = 656.25$$

$$s_u2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_{b,min} = 1.00$$

$$s_u2 = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su2,nominal} = 0.08$,

For calculation of $e_{su2,nominal}$ and y_2 , sh_2, ft_2, f_y2 , it is considered
characteristic value $f_{sy2} = f_s2/1.2$, from table 5.1, TBDY.

y_1 , sh_1, ft_1, f_y1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s2} = f_s = 656.25$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$f_{y_v} = 656.25$$

$$s_{u_v} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_d = 1.00$$

$$s_{u_v} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv,nominal}$ and y_v , sh_v, ft_v, f_{y_v} , it is considered
characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1 , sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{sv} = f_s = 656.25$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.15879823$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.15879823$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.07699308$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 32.82928$$

$$cc (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.22362502$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.22362502$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.10842425$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

--->

$$s_u (4.8) = 0.17214129$$

$$\mu_u = M_{Rc} (4.15) = 3.6072E+008$$

$$u = s_u (4.1) = 8.4581924E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of μ_{u1} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 8.4581924E-005$$

Mu = 3.6072E+008

with full section properties:

b = 250.00

d = 457.00

d' = 43.00

v = 0.00136161

N = 4666.932

fc = 30.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01290198$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01290198$

we ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.05524832$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.0541155

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), $ff_e = 882.7518$

fy = 0.09723711

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), $ff_e = 793.0837$

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) = 0.05494666

bo = 440.00

ho = 190.00

bi2 = 459400.00

psh,min = $\text{Min}(psh_x, psh_y) = 0.00314159$

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) = 0.00314159

Ash = $A_{stir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 500.00

psh,y (5.4d) = 0.00628319

Ash = $A_{stir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 250.00

s = 100.00

fywe = 656.25

fce = 30.00

From ((5.A5), TBDY), TBDY: $cc = 0.00294309$

c = confinement factor = 1.09431

y1 = 0.0025

sh1 = 0.008

ft1 = 787.50

fy1 = 656.25

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 787.50

fy2 = 656.25

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

yv = 0.0025

shv = 0.008

ftv = 787.50

fyv = 656.25

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/ld = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.15879823

2 = Asl,com/(b*d)*(fs2/fc) = 0.15879823

v = Asl,mid/(b*d)*(fsv/fc) = 0.07699308

and confined core properties:

b = 190.00

d = 427.00

d' = 13.00

fcc (5A.2, TBDY) = 32.82928

cc (5A.5, TBDY) = 0.00294309

c = confinement factor = 1.09431

1 = Asl,ten/(b*d)*(fs1/fc) = 0.22362502

2 = Asl,com/(b*d)*(fs2/fc) = 0.22362502

v = Asl,mid/(b*d)*(fsv/fc) = 0.10842425

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is not satisfied

--->

v < vs,c - RHS eq.(4.5) is satisfied

--->

su (4.8) = 0.17214129

Mu = MRc (4.15) = 3.6072E+008

u = su (4.1) = 8.4581924E-005

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 8.4581924E-005$$

$$\mu = 3.6072E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00136161$$

$$N = 4666.932$$

$$f_c = 30.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01290198$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01290198$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0541155$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$f_y = 0.09723711$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 793.0837$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_s e \text{ ((5.4d), TBDY)} = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.00314159$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00628319$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 30.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00294309$

$$c = \text{confinement factor} = 1.09431$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$$fy_1 = 656.25$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 656.25$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.0025$$

$$sh_2 = 0.008$$

$$ft_2 = 787.50$$

$$fy_2 = 656.25$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_{b,min} = 1.00$$

$$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_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.

$$\text{with } fs_2 = fs = 656.25$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$fy_v = 656.25$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 1.00$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_{nominal}$ and 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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 656.25$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.15879823$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.15879823$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.07699308$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 32.82928$$

$$cc (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.22362502$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.22362502$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.10842425$$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->

su (4.8) = 0.17214129
Mu = MRc (4.15) = 3.6072E+008
u = su (4.1) = 8.4581924E-005

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 8.4581924E-005
Mu = 3.6072E+008

with full section properties:

b = 250.00
d = 457.00
d' = 43.00
v = 0.00136161
N = 4666.932
fc = 30.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01290198
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01290198
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.05524832
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.0541155
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 = 882.7518

fy = 0.09723711
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 = 793.0837

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) = 0.05494666
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.00314159

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) = 0.00314159
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431

y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

yv = 0.0025
shv = 0.008
ftv = 787.50
fyv = 656.25
suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.15879823

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.15879823$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07699308$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 32.82928$$

$$c_c (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22362502$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.22362502$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.10842425$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

--->

$$s_u (4.8) = 0.17214129$$

$$M_u = M_{Rc} (4.15) = 3.6072E+008$$

$$u = s_u (4.1) = 8.4581924E-005$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 501229.73$

Calculation of Shear Strength at edge 1, $V_{r1} = 501229.73$

$$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$$

$$V_{Col0} = 501229.73$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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).

$$= 1 \text{ (normal-weight concrete)}$$

$$f_c' = 30.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$M_u = 5.0983467E-013$$

$$V_u = 7.3955710E-032$$

$$d = 0.8 * h = 400.00$$

$$N_u = 4666.932$$

$$A_g = 125000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 329867.229$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

$$V_s \text{ is multiplied by } \phi_{Col} = 1.00$$

$$s/d = 0.25$$

$$V_f ((11-3)-(11.4), ACI 440) = 240803.347$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$$w_f/s_f = 1 \text{ (FRP strips adjacent to one another).}$$

In (11.3) $\sin \theta + \cos \theta$ 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.

$$\text{orientation 1: } \theta = 45^\circ + 90^\circ = 135^\circ$$

$$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = N_L * t / N_{Dir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 457.00$$

$$f_{fe} ((11-5), ACI 440) = 259.312$$

$E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 363854.192$
 $bw = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 501229.73$
 $V_{r2} = V_{CoI} ((10.3), ASCE 41-17) = knl * V_{CoIO}$
 $V_{CoIO} = 501229.73$
 $knl = 1$ (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)
 $f_c' = 30.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 5.0983467E-013$
 $V_u = 7.3955710E-032$
 $d = 0.8 * h = 400.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 329867.229$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$

V_s is multiplied by $Col = 1.00$
 $s/d = 0.25$

$V_f ((11-3)-(11.4), ACI 440) = 240803.347$

$f = 0.95$, 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 θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $tf1 = NL * t / NoDir = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 457.00

$ff_e ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 363854.192$
 $bw = 250.00$

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, $\gamma = 0.85$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 25742.96$
Steel Elasticity, $E_s = 200000.00$
Section Height, $H = 250.00$
Section Width, $W = 500.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_b/d >= 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -8.2193294E-011$
Shear Force, $V_2 = 3021.16$
Shear Force, $V_3 = 1.0147380E-013$
Axial Force, $F = -4665.723$
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, $Db_L = 18.66667$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = 1.0^*$ $u = 0.05702691$
 $u = y + p = 0.05702691$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00923029$ ((4.29), Biskinis Phd)
 $M_y = 9.2818E+007$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 5.0279E+012$
factor = 0.30
 $A_g = 125000.00$
 $f_c' = 30.00$
 $N = 4665.723$
 $E_c * I_g = 1.6760E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 1.8256820E-005$

with $f_y = 525.00$
 $d = 207.00$
 $y = 0.30540153$
 $A = 0.0199978$
 $B = 0.01210998$
 with $p_t = 0.00801334$
 $p_c = 0.00801334$
 $p_v = 0.00388525$
 $N = 4665.723$
 $b = 500.00$
 $\alpha = 0.20772947$
 $y_{comp} = 3.3724867E-005$
 with $f_c^* (12.3, (ACI 440)) = 30.44529$
 $f_c = 30.00$
 $f_l = 0.9425867$
 $b = 500.00$
 $h = 250.00$
 $A_g = 125000.00$
 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, $t_f = N L^* t^* \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 25742.96$
 $y = 0.30493938$
 $A = 0.01980605$
 $B = 0.01202411$
 with $E_s = 200000.00$

 Calculation of ratio l_b/d

 Adequate Lap Length: $l_b/d \geq 1$

 - Calculation of p -

 From table 10-8: $p = 0.04779662$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/d < 1$

shear control ratio $V_y E/V_c \alpha E = 0.21712381$

$d = 207.00$

$s = 0.00$

$t = A_v / (b w^* s) + 2^* t_f / b w^* (f_{fe} / f_s) = 0.00$

$A_v = 157.0796$, 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.

$N U D = 4665.723$

$A_g = 125000.00$

$f_c E = 30.00$

$f_y t E = f_y l E = 0.00$

$p_l = \text{Area_Tot_Long_Rein} / (b^* d) = 0.01991193$

$b = 500.00$

$d = 207.00$

$f_c E = 30.00$

 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

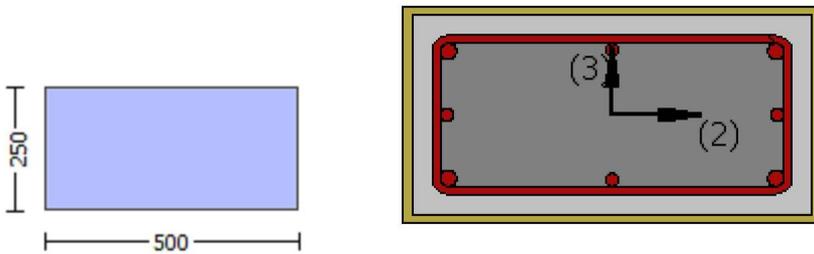
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

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, $\gamma = 0.85$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 20.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 420.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

New material: Concrete Strength, $f_c = f_{cm} = 30.00$

New material: Steel Strength, $f_s = f_{sm} = 525.00$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou,min} = l_b/l_d \geq 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $ε_{fu} = 0.01$
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, $M_a = 3.8701821E-010$
Shear Force, $V_a = -1.0147380E-013$
EDGE -B-
Bending Moment, $M_b = -8.2193294E-011$
Shear Force, $V_b = 1.0147380E-013$
BOTH EDGES
Axial Force, $F = -4665.723$
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, $D_{bL,ten} = 18.66667$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0 \cdot V_n = 347902.508$
 V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoI} = 347902.508$
 $V_{CoI} = 347902.508$
 $k_n = 1.00$
displacement_ductility_demand = 0.00

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '
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)
 $M/Vd = 2.00$
 $M_u = 8.2193294E-011$
 $V_u = 1.0147380E-013$
 $d = 0.8 \cdot h = 200.00$
 $N_u = 4665.723$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 131946.891$
 $A_v = 157079.633$
 $f_y = 420.00$
 $s = 100.00$
 V_s is multiplied by $CoI = 1.00$
 $s/d = 0.50$
 V_f ((11-3)-(11.4), ACI 440) = 109072.851
 $f = 0.95$, for fully-wrapped sections
 $w_f/sf = 1$ (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 θ , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:

total thickness per orientation, $t_{f1} = NL \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$ (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: $V_s + V_f \leq 297085.704$

$b_w = 500.00$

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 $\theta = 1.6572521E-020$

$y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00923029$ ((4.29), Biskinis Phd)

$M_y = 9.2818E+007$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00

From table 10.5, ASCE 41_17: $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 5.0279E+012$

factor = 0.30

$A_g = 125000.00$

$f_c' = 30.00$

$N = 4665.723$

$E_c \cdot I_g = 1.6760E+013$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$

$y_{\text{ten}} = 1.8256820E-005$

with $f_y = 525.00$

$d = 207.00$

$y = 0.30540153$

$A = 0.0199978$

$B = 0.01210998$

with $p_t = 0.00801334$

$p_c = 0.00801334$

$p_v = 0.00388525$

$N = 4665.723$

$b = 500.00$

$\alpha = 0.20772947$

$y_{\text{comp}} = 3.3724867E-005$

with f_c^* (12.3, (ACI 440)) = 30.44529

$f_c = 30.00$

$f_l = 0.9425867$

$b = 500.00$

$h = 250.00$

$A_g = 125000.00$

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, $t_f = NL \cdot t \cdot \cos(b1) = 1.016$

effective strain from (12.5) and (12.12), $e_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 25742.96$

$y = 0.30493938$

A = 0.01980605
B = 0.01202411
with Es = 200000.00

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

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

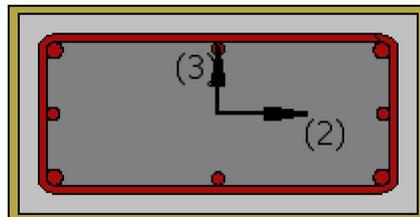
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (u)

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, = 0.85

Mean strength values are used for both shear and moment calculations.

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.09431

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou}, \min \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

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, $V_a = -1.0405794E-032$

EDGE -B-

Shear Force, $V_b = 1.0405794E-032$

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 , $V_e/V_r = 0.21712381$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 88136.71$

with

$M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 1.3221E+008$

$M_{u1+} = 1.3221E+008$, 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

$M_{u1-} = 1.3221E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 1.3221E+008$

$M_{u2+} = 1.3221E+008$, 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

$M_{u2-} = 1.3221E+008$, 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:

$$u = 0.0002015$$

$$Mu = 1.3221E+008$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00150304$$

$$N = 4666.932$$

$$f_c = 30.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01290198$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01290198$$

$$\omega_e \text{ ((5.4c), TBDY)} = a_{se} * \frac{\text{sh}_{\min} * f_{ywe}}{f_{ce}} + \text{Min}(\phi_x, \phi_y) = 0.05524832$$

where $\phi = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.0541155$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$\phi_y = 0.09723711$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 793.0837$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$\text{psh}_{\min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.00314159$$

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)

$$\text{psh}_x \text{ (5.4d)} = 0.00314159$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$\text{psh}_y \text{ (5.4d)} = 0.00628319$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 30.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$f_{t1} = 787.50$$

$$f_{y1} = 656.25$$

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 787.50

fy2 = 656.25

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

yv = 0.0025

shv = 0.008

ftv = 787.50

fyv = 656.25

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered

characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17529176

2 = Asl,com/(b*d)*(fs2/fc) = 0.17529176

v = Asl,mid/(b*d)*(fsv/fc) = 0.08498995

and confined core properties:

b = 440.00

d = 177.00

d' = 13.00

fcc (5A.2, TBDY) = 32.82928

cc (5A.5, TBDY) = 0.00294309

c = confinement factor = 1.09431

1 = Asl,ten/(b*d)*(fs1/fc) = 0.23295708

2 = Asl,com/(b*d)*(fs2/fc) = 0.23295708

v = Asl,mid/(b*d)*(fsv/fc) = 0.11294889

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

v < vs,y2 - LHS eq.(4.5) is satisfied

su (4.9) = 0.23279566

Mu = MRc (4.14) = 1.3221E+008

u = su (4.1) = 0.0002015

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_1

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 0.0002015$

$\mu_1 = 1.3221E+008$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00150304$

$N = 4666.932$

$f_c = 30.00$

α (5A.5, TBDY) = 0.002

Final value of μ_c : $\mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01290198$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.01290198$

μ_{we} ((5.4c), TBDY) = $\alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$

where $f = \alpha * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.0541155$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 882.7518$

$f_y = 0.09723711$

$\alpha_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{fe} = 793.0837$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \text{Cos}(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{f} = 0.015$

α_{se} ((5.4d), TBDY) = 0.05494666

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$\mu_{sh,\min} = \text{Min}(\mu_{sh,x}, \mu_{sh,y}) = 0.00314159$

Expression ((5.4d), TBDY) for $\mu_{sh,\min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\mu_{sh,x}$ (5.4d) = 0.00314159

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 500.00$

$\mu_{sh,y}$ (5.4d) = 0.00628319

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 250.00$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 30.00$$

From ((5.A5), TBDY), TBDY: $cc = 0.00294309$

$$c = \text{confinement factor} = 1.09431$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$$fy_1 = 656.25$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 656.25$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.0025$$

$$sh_2 = 0.008$$

$$ft_2 = 787.50$$

$$fy_2 = 656.25$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_{b,min} = 1.00$$

$$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_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.

$$\text{with } fs_2 = fs = 656.25$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$fy_v = 656.25$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 1.00$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_{nominal}$ and 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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 656.25$$

$$\text{with } Es_v = Es = 200000.00$$

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.17529176$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.17529176$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.08498995$$

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 32.82928$$

$$cc (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.23295708$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.23295708$$

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.11294889$$

Case/Assumption: Unconfined full section - Steel rupture
satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u(4.9) = 0.23279566$$

$$M_u = M_{Rc}(4.14) = 1.3221E+008$$

$$u = s_u(4.1) = 0.0002015$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of M_{u2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 0.0002015$$

$$M_u = 1.3221E+008$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00150304$$

$$N = 4666.932$$

$$f_c = 30.00$$

$$\alpha(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \alpha: \alpha^* = \text{shear_factor} \cdot \text{Max}(\alpha, \alpha_c) = 0.01290198$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \alpha_c = 0.01290198$$

$$\alpha_{we} \text{ ((5.4c), TBDY) } = \alpha_{se} \cdot \text{sh}_{, \min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$$

where $f = \alpha \cdot p_f \cdot f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0541155$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$f_y = 0.09723711$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 793.0837$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL \cdot t \cdot \text{Cos}(\beta_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TBDY) } = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh, \min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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) = 0.00314159
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431

y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y2, sh2,ft2,fy2, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

yv = 0.0025
shv = 0.008
ftv = 787.50
fyv = 656.25
suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17529176

2 = Asl,com/(b*d)*(fs2/fc) = 0.17529176

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08498995$$

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 32.82928$$

$$c_c (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.23295708$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.23295708$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.11294889$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.23279566$$

$$M_u = M_{Rc} (4.14) = 1.3221E+008$$

$$u = s_u (4.1) = 0.0002015$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of M_{u2} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 0.0002015$$

$$M_u = 1.3221E+008$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00150304$$

$$N = 4666.932$$

$$f_c = 30.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01290198$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01290198$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0541155$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$f_y = 0.09723711$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 793.0837$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t^* \text{Cos}(\beta_1) = 1.016$$

fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.05494666
bo = 440.00
ho = 190.00
bi2 = 459400.00

psh,min = Min(psh,x , psh,y) = 0.00314159

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) = 0.00314159
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431

y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

yv = 0.0025
shv = 0.008
ftv = 787.50
fyv = 656.25
suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_nominal$ and yv , shv,ftv,fyv , it is considered characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1, sh1,ft1,fy1$, are also multiplied by $Min(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fsv = fs = 656.25$

with $Esv = Es = 200000.00$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.17529176$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.17529176$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.08498995$$

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 32.82928$$

$$cc (5A.5, TBDY) = 0.00294309$$

c = confinement factor = 1.09431

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.23295708$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.23295708$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.11294889$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < vs,y2$ - LHS eq.(4.5) is satisfied

$$su (4.9) = 0.23279566$$

$$Mu = MRc (4.14) = 1.3221E+008$$

$$u = su (4.1) = 0.0002015$$

Calculation of ratio lb/d

Adequate Lap Length: $lb/d \geq 1$

Calculation of Shear Strength $Vr = Min(Vr1, Vr2) = 405928.36$

Calculation of Shear Strength at edge 1, $Vr1 = 405928.36$

$Vr1 = VCol$ ((10.3), ASCE 41-17) = $knl * VCol0$

$$VCol0 = 405928.36$$

$knl = 1$ (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)

$$fc' = 30.00, \text{ but } fc^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/d = 2.00$$

$$Mu = 4.7466732E-012$$

$$Vu = 1.0405794E-032$$

$$d = 0.8 * h = 200.00$$

$$Nu = 4666.932$$

$$Ag = 125000.00$$

From (11.5.4.8), ACI 318-14: $Vs = 164933.614$

$$Av = 157079.633$$

$$fy = 525.00$$

$$s = 100.00$$

Vs is multiplied by $Col = 1.00$

$$s/d = 0.50$$

$$Vf ((11-3)-(11.4), ACI 440) = 109072.851$$

$f = 0.95$, 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 $V_f(\theta)$, 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: $\theta = 45^\circ$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:

total thickness per orientation, $t_{f1} = NL \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (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: $V_s + V_f \leq 363854.192$

$b_w = 500.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 405928.36$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l \cdot V_{Col0}$

$V_{Col0} = 405928.36$

$k_n l = 1$ (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).

$\gamma = 1$ (normal-weight concrete)

$f_c' = 30.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / V d = 2.00$

$\mu_u = 4.7466732E-012$

$\nu_u = 1.0405794E-032$

$d = 0.8 \cdot h = 200.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 164933.614$

$A_v = 157079.633$

$f_y = 525.00$

$s = 100.00$

V_s is multiplied by $\gamma_{Col} = 1.00$

$s / d = 0.50$

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 α 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: $\theta = 45^\circ$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:

total thickness per orientation, $t_{f1} = NL \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (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: $V_s + V_f \leq 363854.192$

$b_w = 500.00$

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, $\phi = 0.85$
Mean strength values are used for both shear and moment calculations.
Consequently:
New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$
Concrete Elasticity, $E_c = 25742.96$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 656.25$

Section Height, $H = 250.00$
Section Width, $W = 500.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.09431
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou, \min} >= 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
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, $V_a = -7.3955710E-032$
EDGE -B-
Shear Force, $V_b = 7.3955710E-032$
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, $V_e/V_r = 0.47977838$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 240479.187$
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 3.6072E+008$
 $M_{u1+} = 3.6072E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $M_{u1-} = 3.6072E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 3.6072E+008$

Mu2+ = 3.6072E+008, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

Mu2- = 3.6072E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu1+

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 8.4581924E-005$$

$$Mu = 3.6072E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00136161$$

$$N = 4666.932$$

$$f_c = 30.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01290198$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01290198$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0541155$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$f_y = 0.09723711$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 793.0837$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s e \text{ ((5.4d), TBDY)} = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.00314159$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00628319$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 30.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00294309$

$$c = \text{confinement factor} = 1.09431$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$$fy_1 = 656.25$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/ld = 1.00$$

$$su_1 = 0.4 * esu_{1, \text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

From table 5A.1, TBDY: $esu_{1, \text{nominal}} = 0.08$,

For calculation of $esu_{1, \text{nominal}}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 656.25$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.0025$$

$$sh_2 = 0.008$$

$$ft_2 = 787.50$$

$$fy_2 = 656.25$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/lb, \min = 1.00$$

$$su_2 = 0.4 * esu_{2, \text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

From table 5A.1, TBDY: $esu_{2, \text{nominal}} = 0.08$,

For calculation of $esu_{2, \text{nominal}}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 656.25$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$fy_v = 656.25$$

$$su_v = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/ld = 1.00$$

$$su_v = 0.4 * esu_{v, \text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

From table 5A.1, TBDY: $esu_{v, \text{nominal}} = 0.08$,

considering characteristic value $fsy_v = fsv/1.2$, from table 5.1, TBDY

For calculation of $esu_{v, \text{nominal}}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsy_v = fsv/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 656.25$$

$$\text{with } Es_v = Es = 200000.00$$

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.15879823$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.15879823$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.07699308$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, \text{TBDY}) = 32.82928$$

$$cc (5A.5, \text{TBDY}) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.22362502$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.22362502$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.10842425$$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied
--->
 $v < v_{s,c}$ - RHS eq.(4.5) is satisfied
--->

s_u (4.8) = 0.17214129
 $M_u = M_{Rc}$ (4.15) = 3.6072E+008
 $u = s_u$ (4.1) = 8.4581924E-005

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of M_{u1} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 8.4581924E-005$
 $M_u = 3.6072E+008$

with full section properties:

$b = 250.00$
 $d = 457.00$
 $d' = 43.00$
 $v = 0.00136161$
 $N = 4666.932$
 $f_c = 30.00$
 α (5A.5, TBDY) = 0.002

Final value of α : $\alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01290198$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\alpha = 0.01290198$

w_e ((5.4c), TBDY) = $\alpha s_e * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$

where $f = \alpha^* p_f^* f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.0541155$
 $\alpha_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.004064$
 $b_w = 500.00$
effective stress from (A.35), $f_{f,e} = 882.7518$

 $f_y = 0.09723711$
 $\alpha_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$
 $b_w = 250.00$
effective stress from (A.35), $f_{f,e} = 793.0837$

 $R = 40.00$
Effective FRP thickness, $t_f = N L^* t \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{f,e} = 0.015$
 α_s ((5.4d), TBDY) = 0.05494666
 $b_o = 440.00$
 $h_o = 190.00$
 $b_i^2 = 459400.00$

$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$

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) = 0.00314159
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431

y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

yv = 0.0025
shv = 0.008
ftv = 787.50
fyv = 656.25
suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.15879823

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.15879823$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07699308$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 32.82928$$

$$c_c (5A.5, TBDY) = 0.00294309$$

$$c = \text{confinement factor} = 1.09431$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22362502$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.22362502$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.10842425$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

--->

$$s_u (4.8) = 0.17214129$$

$$\mu_u = M_{Rc} (4.15) = 3.6072E+008$$

$$u = s_u (4.1) = 8.4581924E-005$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_{u2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 8.4581924E-005$$

$$\mu_u = 3.6072E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00136161$$

$$N = 4666.932$$

$$f_c = 30.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01290198$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01290198$$

$$w_e ((5.4c), TBDY) = a_s e^* s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05524832$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0541155$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 882.7518$$

$$f_y = 0.09723711$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 793.0837$$

R = 40.00
Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase((5.4d), TBDY) = 0.05494666$
 $bo = 440.00$
 $ho = 190.00$
 $bi2 = 459400.00$
 $psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00314159$

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)

$psh_{,x}(5.4d) = 0.00314159$
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $bk = 500.00$

$psh_{,y}(5.4d) = 0.00628319$
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $bk = 250.00$

$s = 100.00$
 $f_{ywe} = 656.25$
 $f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00294309$
 $c = \text{confinement factor} = 1.09431$

$y_1 = 0.0025$
 $sh_1 = 0.008$
 $ft_1 = 787.50$
 $fy_1 = 656.25$
 $su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lo_{,min} = lb/ld = 1.00$

$su_1 = 0.4 \cdot esu_{1,nominal}((5.5), TBDY) = 0.032$

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 $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lo_{,min} = lb/lb_{,min} = 1.00$

$su_2 = 0.4 \cdot esu_{2,nominal}((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $fy_v = 656.25$
 $suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lo_{u,min} = lb/d = 1.00

su_v = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fs_{yv} = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and y_v, sh_v,ft_v,fy_v, it is considered characteristic value fs_{yv} = fsv/1.2, from table 5.1, TBDY.

y₁, sh₁,ft₁,fy₁, are also multiplied by Min(1,1.25*(lb/d)^{2/3}), from 10.3.5, ASCE41-17.

with fsv = fs = 656.25

with Es_v = Es = 200000.00

1 = Asl_{ten}/(b*d)*(fs₁/fc) = 0.15879823

2 = Asl_{com}/(b*d)*(fs₂/fc) = 0.15879823

v = Asl_{mid}/(b*d)*(fsv/fc) = 0.07699308

and confined core properties:

b = 190.00

d = 427.00

d' = 13.00

fcc (5A.2, TBDY) = 32.82928

cc (5A.5, TBDY) = 0.00294309

c = confinement factor = 1.09431

1 = Asl_{ten}/(b*d)*(fs₁/fc) = 0.22362502

2 = Asl_{com}/(b*d)*(fs₂/fc) = 0.22362502

v = Asl_{mid}/(b*d)*(fsv/fc) = 0.10842425

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

v < vs_{y2} - LHS eq.(4.5) is not satisfied

v < vs_c - RHS eq.(4.5) is satisfied

su (4.8) = 0.17214129

Mu = MRc (4.15) = 3.6072E+008

u = su (4.1) = 8.4581924E-005

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu₂-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 8.4581924E-005

Mu = 3.6072E+008

with full section properties:

b = 250.00

d = 457.00

d' = 43.00

v = 0.00136161

N = 4666.932

fc = 30.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01290198

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01290198

we ((5.4c), TBDY) = ase* sh_{min}*fy_{we}/f_{ce}+Min(fx, fy) = 0.05524832

where f = af*pf*ffe/f_{ce} is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.0541155

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), $ff,e = 882.7518$

fy = 0.09723711
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), $ff,e = 793.0837$

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) = 0.05494666
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.00314159
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) = 0.00314159
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 656.25
fce = 30.00
From ((5.A5), TBDY), TBDY: cc = 0.00294309
c = confinement factor = 1.09431
y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 1.00
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by $Min(1, 1.25*(lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs1 = fs = 656.25$
with $Es1 = Es = 200000.00$

y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $es_{u2_nominal} = 0.08$,

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 $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$fy_v = 656.25$

$s_{uv} = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$lo/lo_{u,min} = lb/d = 1.00$

$s_{uv} = 0.4 \cdot es_{uv_nominal} ((5.5), TBDY) = 0.032$

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 $fs_v = fs = 656.25$

with $Es_v = Es = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.15879823$

2 = $As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.15879823$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.07699308$

and confined core properties:

$b = 190.00$

$d = 427.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 32.82928$

$cc (5A.5, TBDY) = 0.00294309$

$c = \text{confinement factor} = 1.09431$

1 = $As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.22362502$

2 = $As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.22362502$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.10842425$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

--->

$s_u (4.8) = 0.17214129$

$\mu_u = MR_c (4.15) = 3.6072E+008$

$u = s_u (4.1) = 8.4581924E-005$

Calculation of ratio lb/d

Adequate Lap Length: $lb/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 501229.73$

Calculation of Shear Strength at edge 1, $V_{r1} = 501229.73$

$V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = knl \cdot V_{Co10}$

$V_{Co10} = 501229.73$

$knl = 1$ (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)

$f_c' = 30.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$\mu_u = 5.0983467E-013$$

$$\mu_v = 7.3955710E-032$$

$$d = 0.8 \cdot h = 400.00$$

$$N_u = 4666.932$$

$$A_g = 125000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 329867.229$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

$$V_s \text{ is multiplied by } \phi_{col} = 1.00$$

$$s/d = 0.25$$

$$V_f \text{ ((11-3)-(11.4), ACI 440) } = 240803.347$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$$w_f/s_f = 1 \text{ (FRP strips adjacent to one another).}$$

In (11.3) $\sin \theta + \cos \theta$ 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.

$$\text{orientation 1: } \theta = 45^\circ \Rightarrow \theta = 90^\circ$$

$$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = N_L \cdot t / N_{oDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440) } = 457.00$$

$$f_{fe} \text{ ((11-5), ACI 440) } = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 363854.192$$

$$b_w = 250.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 501229.73$

$$V_{r2} = V_{col} \text{ ((10.3), ASCE 41-17) } = k_{nl} \cdot V_{col0}$$

$$V_{col0} = 501229.73$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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).

$$= 1 \text{ (normal-weight concrete)}$$

$$f_c' = 30.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$\mu_u = 5.0983467E-013$$

$$\mu_v = 7.3955710E-032$$

$$d = 0.8 \cdot h = 400.00$$

$$N_u = 4666.932$$

$$A_g = 125000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 329867.229$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

$$V_s \text{ is multiplied by } \phi_{col} = 1.00$$

$$s/d = 0.25$$

$$V_f \text{ ((11-3)-(11.4), ACI 440) } = 240803.347$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$$w_f/s_f = 1 \text{ (FRP strips adjacent to one another).}$$

In (11.3) $\sin \theta + \cos \theta$ 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.

$$\text{orientation 1: } \theta = 45^\circ \Rightarrow \theta = 90^\circ$$

$$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = N_L \cdot t / N_{oDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440) } = 457.00$$

$$f_{fe} \text{ ((11-5), ACI 440) } = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 363854.192$

$b_w = 250.00$

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, $\gamma = 0.85$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 30.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/d \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -0.00051461$

Shear Force, $V_2 = 3021.16$

Shear Force, $V_3 = 1.0147380E-013$

Axial Force, $F = -4665.723$

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, $Db_L = 18.66667$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u, R = 1.0^*$ $u = 0.05550162$
 $u = y + p = 0.05550162$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00102938$ ((4.29), Biskinis Phd)
 $M_y = 2.0703E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 2.0112E+013$
factor = 0.30
Ag = 125000.00
fc' = 30.00
N = 4665.723
 $E_c * I_g = 6.7039E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 7.9424748E-006$
with $f_y = 525.00$
d = 457.00
 $y = 0.27680192$
A = 0.01811617
B = 0.00994561
with $p_t = 0.00725935$
pc = 0.00725935
pv = 0.00351968
N = 4665.723
b = 250.00
" = 0.0940919
 $y_{comp} = 1.6862744E-005$
with f_c^* (12.3, (ACI 440)) = 30.44585
fc = 30.00
fl = 0.9425867
b = 250.00
h = 500.00
Ag = 125000.00
From (12.9), ACI 440: $k_a = 0.15087868$
 $g = p_t + pc + pv = 0.01803838$
rc = 40.00
Ae/Ac = 0.60351471
Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
fu = 0.01
Ef = 64828.00
Ec = 25742.96
 $y = 0.27624705$
A = 0.01794246
B = 0.00986782
with $E_s = 200000.00$

Calculation of ratio l_b / l_d

Adequate Lap Length: $l_b / l_d \geq 1$

- Calculation of p -

From table 10-8: $p = 0.05447223$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b / l_d < 1$

shear control ratio $V_{yE}/V_{CoIE} = 0.47977838$

$d = 457.00$

$s = 0.00$

$t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.00$

$A_v = 157.0796$, 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.

$NUD = 4665.723$

$A_g = 125000.00$

$f_{cE} = 30.00$

$f_{yE} = f_{yI} = 0.00$

$p_l = \text{Area_Tot_Long_Rein}/(b*d) = 0.01803838$

$b = 250.00$

$d = 457.00$

$f_{cE} = 30.00$

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (b)
