

Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

column C1, Floor 1

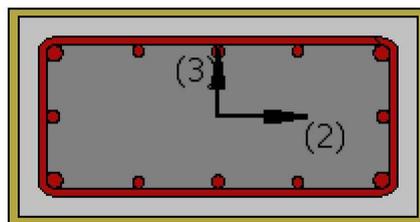
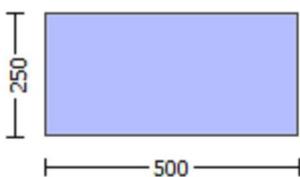
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity 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, $\gamma = 1.00$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

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

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

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

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Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{o,min} = l_b/l_d = 0.30$

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, $M_a = -1.1597E+007$

Shear Force, $V_a = -3853.513$

EDGE -B-

Bending Moment, $M_b = 33515.919$

Shear Force, $V_b = 3853.513$

BOTH EDGES

Axial Force, $F = -4772.994$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

-Middle: $As_{l,mid} = 1017.876$

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

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 316019.354$

V_n ((10.3), ASCE 41-17) = $knI \cdot V_{CoI} = 316019.354$

$V_{CoI} = 316019.354$

$knI = 1.00$

displacement_ductility_demand = 0.02801902

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

= 1 (normal-weight concrete)

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

$M/Vd = 4.00$

$M_u = 1.1597E+007$

$V_u = 3853.513$

$d = 0.8 \cdot h = 400.00$
 $Nu = 4772.994$
 $Ag = 125000.00$
 From (11.5.4.8), ACI 318-14: $Vs = 251327.412$
 $Av = 157079.633$
 $fy = 400.00$
 $s = 100.00$
 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 $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $a_1 = 45^\circ$ and $a_2 = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta_1 = b_1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, a_1)|, |Vf(-45, a_1)|)$, with:
 total thickness per orientation, $tf_1 = NL \cdot t / \text{NoDir} = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 457.00
 ffe ((11-5), ACI 440) = 259.312
 $Ef = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.01$
 From (11-11), ACI 440: $Vs + Vf \leq 265721.532$
 $bw = 250.00$

 displacement_ductility_demand is calculated as δ / y

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

 From analysis, chord rotation $\theta = 0.00019559$
 $y = (My \cdot Ls / 3) / Eleff = 0.00698058$ ((4.29), Biskinis Phd))
 $My = 1.1427E+008$
 $Ls = M/V$ (with $Ls > 0.1 \cdot L$ and $Ls < 2 \cdot L$) = 3009.429
 From table 10.5, ASCE 41_17: $Eleff = \text{factor} \cdot Ec \cdot Ig = 1.6421E+013$
 $\text{factor} = 0.30$
 $Ag = 125000.00$
 $fc' = 20.00$
 $N = 4772.994$
 $Ec \cdot Ig = 5.4737E+013$

 Calculation of Yielding Moment My

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

 $y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.0111358E-006$
 with ((10.1), ASCE 41-17) $fy = \text{Min}(fy, 1.25 \cdot fy \cdot (lb/d)^{2/3}) = 248.9644$
 $d = 457.00$
 $y = 0.3209156$
 $A = 0.0235957$
 $B = 0.01298394$
 with $pt = 0.00725935$
 $pc = 0.00725935$
 $pv = 0.0089092$
 $N = 4772.994$
 $b = 250.00$
 $\theta = 0.0940919$
 $y_{comp} = 1.1987390E-005$
 with $fc' = 20.44423$ (12.3, (ACI 440)) = 20.44423
 $fc = 20.00$

$f_l = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $A_g = 125000.00$
From (12.9), ACI 440: $k_a = 0.15033165$
 $g = p_t + p_c + p_v = 0.02342789$
 $r_c = 40.00$
 $A_e/A_c = 0.60132659$
Effective FRP thickness, $t_f = NL * t * \cos(\theta) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.31958736$
 $A = 0.02330859$
 $B = 0.01281613$
with $E_s = 200000.00$

Calculation of ratio I_b/I_d

Inadequate Lap Length with $I_b/I_d = 0.30$

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

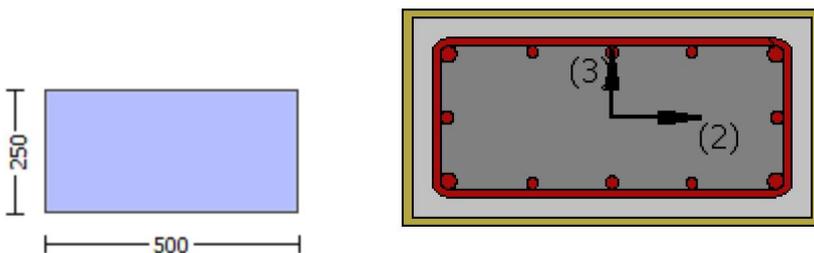
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

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, $k = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

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Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{o,min} = 0.30$

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, $V_a = -3.6206709E-031$

EDGE -B-

Shear Force, $V_b = 3.6206709E-031$

BOTH EDGES

Axial Force, $F = -4716.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression: $A_{sl,c} = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1137.257$

-Compression: $A_{sl,com} = 1137.257$

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

Calculation of Shear Capacity ratio, $V_e/V_r = 0.1467291$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 52248.951$

with

$$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 7.8373E+007$$

$M_{u1+} = 7.8373E+007$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 7.8373E+007$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 7.8373E+007$$

$M_{u2+} = 7.8373E+007$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 7.8373E+007$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of M_{u1+}

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

$$\phi_u = 3.3776478E-005$$

$$M_u = 7.8373E+007$$

with full section properties:

$$b = 500.00$$

$$d = 208.00$$

$$d' = 42.00$$

$$v = 0.0022677$$

$$N = 4716.808$$

$$f_c = 20.00$$

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

$$\text{Final value of } \phi_{cu}: \phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01470636$$

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

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01470636$$

$$\omega_{ve} \text{ ((5.4c), TBDY)} = \alpha_{se} * \text{sh}_{,min} * f_{yve} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07848902$$

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

$$\phi_{fx} = 0.07705054$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$b_w = 500.00$$

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

$$\phi_{fy} = 0.12936483$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

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

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

$$\text{psh}_{,x} \text{ (5.4d)} = 0.00314159$$

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

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

$$b_k = 500.00$$

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

s = 100.00
fywe = 555.55
fce = 20.00

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

y1 = 0.00129669
sh1 = 0.0044814
ft1 = 373.4467
fy1 = 311.2056
su1 = 0.00512

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

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669
sh2 = 0.0044814
ft2 = 373.4467
fy2 = 311.2056
su2 = 0.00512

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

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669
shv = 0.0044814
ftv = 373.4467
fyv = 311.2056
suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17015411

2 = Asl,com/(b*d)*(fs2/fc) = 0.17015411

v = Asl,mid/(b*d)*(fsv/fc) = 0.06016499

and confined core properties:

b = 440.00
d = 178.00
d' = 12.00

fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.22594519
2 = Asl,com/(b*d)*(fs2/fc) = 0.22594519
v = Asl,mid/(b*d)*(fsv/fc) = 0.07989222

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

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

--->
su (4.9) = 0.27122702
Mu = MRc (4.14) = 7.8373E+007
u = su (4.1) = 3.3776478E-005

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu1-

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

u = 3.3776478E-005
Mu = 7.8373E+007

with full section properties:

b = 500.00
d = 208.00
d' = 42.00
v = 0.0022677
N = 4716.808
fc = 20.00
co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01470636

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

From (5.4b), TBDY: cu = 0.01470636

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+ Min(fx, fy) = 0.07848902

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

fx = 0.07705054

af = 0.45253333

b = 500.00

h = 250.00

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

bw = 500.00

effective stress from (A.35), ff,e = 837.9178

fy = 0.12936483

af = 0.45253333

b = 250.00

h = 500.00

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

bw = 250.00

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

R = 40.00

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

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 = 555.55

fce = 20.00

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

c = confinement factor = 1.13916

y1 = 0.00129669

sh1 = 0.0044814

ft1 = 373.4467

fy1 = 311.2056

su1 = 0.00512

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

lo/lou,min = lb/lb = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669

sh2 = 0.0044814

ft2 = 373.4467

fy2 = 311.2056

su2 = 0.00512

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

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669

shv = 0.0044814

ftv = 373.4467

fyv = 311.2056

suv = 0.00512

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

lo/lou,min = lb/lb = 0.30

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

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

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

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

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

with $f_{sv} = f_s = 311.2056$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.17015411$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.17015411$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.06016499$

and confined core properties:

$b = 440.00$

$d = 178.00$

$d' = 12.00$

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

$cc \text{ (5A.5, TBDY)} = 0.00339158$

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

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.22594519$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.22594519$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.07989222$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su \text{ (4.9)} = 0.27122702$

$Mu = MRc \text{ (4.14)} = 7.8373E+007$

$u = su \text{ (4.1)} = 3.3776478E-005$

Calculation of ratio lb/d

Inadequate Lap Length with $lb/d = 0.30$

Calculation of Mu_{2+}

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

$u = 3.3776478E-005$

$Mu = 7.8373E+007$

with full section properties:

$b = 500.00$

$d = 208.00$

$d' = 42.00$

$v = 0.0022677$

$N = 4716.808$

$f_c = 20.00$

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

Final value of cu : $cu^* = \text{shear_factor} \cdot \text{Max}(cu, cc) = 0.01470636$

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

From (5.4b), TBDY: $cu = 0.01470636$

$w_e \text{ ((5.4c), TBDY)} = ase \cdot sh_{,min} \cdot fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.07848902$

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

 $fx = 0.07705054$

$af = 0.45253333$

$b = 500.00$

$h = 250.00$

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

$bw = 500.00$

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

$fy = 0.12936483$

$af = 0.45253333$

$b = 250.00$

$h = 500.00$

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

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

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

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$
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, $n_s = 2.00$
 $b_k = 250.00$

$s = 100.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$
From ((5.A5), TBDY), TBDY: $c_c = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $y_1 = 0.00129669$
 $sh_1 = 0.0044814$
 $ft_1 = 373.4467$
 $fy_1 = 311.2056$
 $su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30$
 $su_1 = 0.4 * esu1_{nominal} ((5.5), TBDY) = 0.032$
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 $fs_1 = fs = 311.2056$
with $Es_1 = Es = 200000.00$

$y_2 = 0.00129669$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4467$
 $fy_2 = 311.2056$
 $su_2 = 0.00512$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$
 $su_2 = 0.4 * esu2_{nominal} ((5.5), TBDY) = 0.032$
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_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs_2 = fs = 311.2056$
with $Es_2 = Es = 200000.00$

$y_v = 0.00129669$
 $sh_v = 0.0044814$
 $ft_v = 373.4467$
 $fy_v = 311.2056$

suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17015411

2 = Asl,com/(b*d)*(fs2/fc) = 0.17015411

v = Asl,mid/(b*d)*(fsv/fc) = 0.06016499

and confined core properties:

b = 440.00

d = 178.00

d' = 12.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = Asl,ten/(b*d)*(fs1/fc) = 0.22594519

2 = Asl,com/(b*d)*(fs2/fc) = 0.22594519

v = Asl,mid/(b*d)*(fsv/fc) = 0.07989222

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.27122702

Mu = MRc (4.14) = 7.8373E+007

u = su (4.1) = 3.3776478E-005

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2-

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

u = 3.3776478E-005

Mu = 7.8373E+007

with full section properties:

b = 500.00

d = 208.00

d' = 42.00

v = 0.0022677

N = 4716.808

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01470636

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

From (5.4b), TBDY: cu = 0.01470636

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.07848902

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

fx = 0.07705054

af = 0.45253333

b = 500.00

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

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

R = 40.00
Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$
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 = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00129669
sh1 = 0.0044814
ft1 = 373.4467
fy1 = 311.2056
su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.30
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 $fs1 = fs = 311.2056$
with $Es1 = Es = 200000.00$

y2 = 0.00129669
sh2 = 0.0044814
ft2 = 373.4467
fy2 = 311.2056
su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 0.30
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

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

For calculation of $es_{2_nominal}$ 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 $fs_2 = fs = 311.2056$

with $Es_2 = Es = 200000.00$

$y_v = 0.00129669$

$sh_v = 0.0044814$

$ft_v = 373.4467$

$fy_v = 311.2056$

$suv = 0.00512$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$lo/lo_{u,min} = lb/d = 0.30$

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

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 $fs_v = fs = 311.2056$

with $Es_v = Es = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.17015411$

2 = $As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.17015411$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.06016499$

and confined core properties:

$b = 440.00$

$d = 178.00$

$d' = 12.00$

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

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

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

1 = $As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.22594519$

2 = $As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.22594519$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.07989222$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.27122702$

$Mu = MRc (4.14) = 7.8373E+007$

$u = su (4.1) = 3.3776478E-005$

Calculation of ratio lb/d

Inadequate Lap Length with $lb/d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 356091.268$

Calculation of Shear Strength at edge 1, $V_{r1} = 356091.268$

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

$V_{Col0} = 356091.268$

$knl = 1$ (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)

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

$M/d = 2.00$

$Mu = 6.4608054E-012$

$V_u = 3.6206709E-031$
 $d = 0.8 \cdot h = 200.00$
 $N_u = 4716.808$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 139624.944$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 100.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.50$
 V_f ((11-3)-(11.4), ACI 440) = 109599.773
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 208.00
 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: $V_s + V_f \leq 297085.704$
 $b_w = 500.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 356091.268$
 $V_{r2} = V_{\text{Col}}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{\text{Col}0}$
 $V_{\text{Col}0} = 356091.268$
 $k_{nl} = 1$ (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).

$\gamma = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 6.4608054E-012$
 $V_u = 3.6206709E-031$
 $d = 0.8 \cdot h = 200.00$
 $N_u = 4716.808$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 139624.944$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 100.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.50$
 V_f ((11-3)-(11.4), ACI 440) = 109599.773
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 208.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 297085.704$

bw = 500.00

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

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

Constant Properties

Knowledge Factor, $\gamma = 1.00$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

Section Height, $H = 250.00$
Section Width, $W = 500.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.13916
Element Length, $L = 3000.00$
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
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, $V_a = 8.5800179E-032$
EDGE -B-
Shear Force, $V_b = -8.5800179E-032$
BOTH EDGES
Axial Force, $F = -4716.808$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 2676.637$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{l,ten} = 829.3805$
-Compression: $As_{l,com} = 829.3805$

-Middle: Asl,mid = 1017.876

Calculation of Shear Capacity ratio , $V_e/V_r = 0.27523624$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 112690.591$

with

$M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 1.6904E+008$

$\mu_{u1+} = 1.6904E+008$, 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

$\mu_{u1-} = 1.6904E+008$, 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

$M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 1.6904E+008$

$\mu_{u2+} = 1.6904E+008$, 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

$\mu_{u2-} = 1.6904E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of μ_{u1+}

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

$\mu_u = 1.4516822E-005$

$\mu_u = 1.6904E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00206425$

$N = 4716.808$

$f_c = 20.00$

α_{co} (5A.5, TBDY) = 0.002

Final value of μ_{cu} : $\mu_{cu}^* = \text{shear_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.01470636$

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

From (5.4b), TBDY: $\mu_{cu} = 0.01470636$

μ_{cu} ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$

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

$f_x = 0.07705054$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

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

$bw = 500.00$

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

$f_y = 0.12936483$

$\alpha_f = 0.45253333$

$b = 250.00$

$h = 500.00$

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

$bw = 250.00$

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

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

α_{se} ((5.4d), TBDY) = 0.05494666

$b_o = 440.00$

$h_o = 190.00$

$$bi2 = 459400.00$$

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

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)

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

$$Ash = Astir*ns = 78.53982$$

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

$$bk = 500.00$$

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

$$Ash = Astir*ns = 78.53982$$

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

$$bk = 250.00$$

$$s = 100.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

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

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

$$y1 = 0.00129669$$

$$sh1 = 0.0044814$$

$$ft1 = 373.4467$$

$$fy1 = 311.2056$$

$$su1 = 0.00512$$

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

$$lo/lou,min = lb/ld = 0.30$$

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

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.

$$\text{with } fs1 = fs = 311.2056$$

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

$$y2 = 0.00129669$$

$$sh2 = 0.0044814$$

$$ft2 = 373.4467$$

$$fy2 = 311.2056$$

$$su2 = 0.00512$$

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

$$lo/lou,min = lb/lb,min = 0.30$$

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

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

$$\text{with } fs2 = fs = 311.2056$$

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

$$yv = 0.00129669$$

$$shv = 0.0044814$$

$$ftv = 373.4467$$

$$fyv = 311.2056$$

$$suv = 0.00512$$

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

$$lo/lou,min = lb/ld = 0.30$$

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

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 $f_{sv} = f_s = 311.2056$
with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.11295746$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11295746$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.13862961$

and confined core properties:

$b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.15907051$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.15907051$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.19522289$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.2282401$
 $Mu = MRc (4.14) = 1.6904E+008$
 $u = su (4.1) = 1.4516822E-005$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Mu_1 -

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

$u = 1.4516822E-005$
 $Mu = 1.6904E+008$

with full section properties:

$b = 250.00$
 $d = 457.00$
 $d' = 43.00$
 $v = 0.00206425$
 $N = 4716.808$
 $f_c = 20.00$
 $co (5A.5, TBDY) = 0.002$
Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01470636$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $cu = 0.01470636$
 $w_e ((5.4c), TBDY) = ase * sh_{,min} * fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.07848902$
where $f = af * pf * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $fx = 0.07705054$
 $af = 0.45253333$
 $b = 500.00$
 $h = 250.00$
From EC8 A.4.4.3(6), $pf = 2t_f/bw = 0.004064$
 $bw = 500.00$
effective stress from (A.35), $f_{f,e} = 837.9178$

$fy = 0.12936483$
 $af = 0.45253333$
 $b = 250.00$
 $h = 500.00$
From EC8 A.4.4.3(6), $pf = 2t_f/bw = 0.008128$
 $bw = 250.00$

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

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

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

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

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

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, $n_s = 2.00$

$b_k = 250.00$

$s = 100.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

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

$y_1 = 0.00129669$

$sh_1 = 0.0044814$

$ft_1 = 373.4467$

$fy_1 = 311.2056$

$su_1 = 0.00512$

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

$l_o/l_{o,min} = l_b/l_d = 0.30$

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

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 $fs_1 = fs = 311.2056$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00129669$

$sh_2 = 0.0044814$

$ft_2 = 373.4467$

$fy_2 = 311.2056$

$su_2 = 0.00512$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$

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

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 $fs_2 = fs = 311.2056$

with $Es_2 = Es = 200000.00$

$y_v = 0.00129669$

$sh_v = 0.0044814$

$ft_v = 373.4467$

$fy_v = 311.2056$

$suv = 0.00512$

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

$l_0/l_{0u,min} = l_b/l_d = 0.30$

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

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, fy_v , it is considered
characteristic value $f_{sv} = f_{sv}/1.2$, 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 $f_{sv} = f_s = 311.2056$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.11295746$

$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.11295746$

$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.13862961$

and confined core properties:

$b = 190.00$

$d = 427.00$

$d' = 13.00$

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

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

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

$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.15907051$

$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.15907051$

$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.19522289$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$s_u (4.9) = 0.2282401$

$M_u = M_{Rc} (4.14) = 1.6904E+008$

$u = s_u (4.1) = 1.4516822E-005$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u2+}

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

$u = 1.4516822E-005$

$M_u = 1.6904E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00206425$

$N = 4716.808$

$f_c = 20.00$

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

Final value of c_u : $c_u * = \text{shear_factor} * \text{Max}(c_u, cc) = 0.01470636$

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

From (5.4b), TBDY: $c_u = 0.01470636$

$w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$

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

$f_x = 0.07705054$

$a_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$
 $bw = 500.00$
effective stress from (A.35), $ff,e = 837.9178$

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

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

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, $ns = 2.00$
 $bk = 250.00$

$s = 100.00$
 $fywe = 555.55$
 $fce = 20.00$

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

$y1 = 0.00129669$
 $sh1 = 0.0044814$
 $ft1 = 373.4467$
 $fy1 = 311.2056$
 $su1 = 0.00512$

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

$lo/lou,min = lb/d = 0.30$

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

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 $fs1 = fs = 311.2056$

with $Es1 = Es = 200000.00$

$y2 = 0.00129669$
 $sh2 = 0.0044814$
 $ft2 = 373.4467$
 $fy2 = 311.2056$
 $su2 = 0.00512$

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

$lo/lou,min = lb/lb,min = 0.30$

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

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

with $fs_2 = fs = 311.2056$

with $Es_2 = Es = 200000.00$

$y_v = 0.00129669$

$sh_v = 0.0044814$

$ft_v = 373.4467$

$fy_v = 311.2056$

$suv = 0.00512$

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

$l_o/l_{o,min} = l_b/l_d = 0.30$

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

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

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

For calculation of $es_{uv_nominal}$ and y_v , sh_v, ft_v, fy_v , it is considered

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

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

with $f_{sv} = fs = 311.2056$

with $Es_v = Es = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.11295746$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.11295746$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.13862961$

and confined core properties:

$b = 190.00$

$d = 427.00$

$d' = 13.00$

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

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

c = confinement factor = 1.13916

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.15907051$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.15907051$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.19522289$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.2282401$

$Mu = MRc (4.14) = 1.6904E+008$

$u = su (4.1) = 1.4516822E-005$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Mu_2 -

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

$u = 1.4516822E-005$

$Mu = 1.6904E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00206425$

$N = 4716.808$

$f_c = 20.00$

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

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01470636$

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

From (5.4b), TBDY: $c_u = 0.01470636$

w_e ((5.4c), TBDY) = $ase * sh_{\min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$

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

 $f_x = 0.07705054$

$af = 0.45253333$

$b = 500.00$

$h = 250.00$

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

$bw = 500.00$

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

 $f_y = 0.12936483$

$af = 0.45253333$

$b = 250.00$

$h = 500.00$

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

$bw = 250.00$

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

 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

ase ((5.4d), TBDY) = 0.05494666

$bo = 440.00$

$ho = 190.00$

$bi2 = 459400.00$

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

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, $n_s = 2.00$

$bk = 250.00$

 $s = 100.00$

$fy_{we} = 555.55$

$f_{ce} = 20.00$

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

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

$y1 = 0.00129669$

$sh1 = 0.0044814$

$ft1 = 373.4467$

$fy1 = 311.2056$

$su1 = 0.00512$

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

$lo/lo_{\min} = lb/ld = 0.30$

$su1 = 0.4 * esu1_{\text{nominal}}$ ((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 $fs1 = fs = 311.2056$

with $Es1 = Es = 200000.00$

$y2 = 0.00129669$

$sh_2 = 0.0044814$
 $ft_2 = 373.4467$
 $fy_2 = 311.2056$
 $su_2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/lb,min = 0.30$
 $su_2 = 0.4*esu_2,nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_2,nominal = 0.08$,
 For calculation of $esu_2,nominal$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 311.2056$
 with $Es_2 = Es = 200000.00$
 $yv = 0.00129669$
 $shv = 0.0044814$
 $ftv = 373.4467$
 $fyv = 311.2056$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 0.30$
 $suv = 0.4*esuv,nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv,nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv,nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 311.2056$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.11295746$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.11295746$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.13862961$
 and confined core properties:
 $b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.15907051$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.15907051$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.19522289$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs,y_2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.2282401$
 $Mu = MRc (4.14) = 1.6904E+008$
 $u = su (4.1) = 1.4516822E-005$

 Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

 Calculation of Shear Strength $Vr = Min(Vr1, Vr2) = 409432.244$

 Calculation of Shear Strength at edge 1, $Vr1 = 409432.244$
 $Vr1 = VCol ((10.3), ASCE 41-17) = knl*VColO$
 $VColO = 409432.244$

$k_{nl} = 1$ (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).

$\lambda = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 8.5689464E-013$
 $V_u = 8.5800179E-032$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4716.808$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 279249.888$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 100.00$
 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 $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta = 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|)$, with:
total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_{e} = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 409432.244$

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

$V_{Col0} = 409432.244$

$k_{nl} = 1$ (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).

$\lambda = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 8.5689464E-013$
 $V_u = 8.5800179E-032$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4716.808$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 279249.888$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 100.00$
 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 $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = b_1 + 90^\circ = 90.00$
Vf = Min(|Vf(45, 1)|, |Vf(-45, a1)|), with:
total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.016$
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: $V_s + V_f \leq 297085.704$
bw = 250.00

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

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

Constant Properties

Knowledge Factor, $\gamma = 1.00$
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$
Section Height, $H = 250.00$
Section Width, $W = 500.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_b / l_d = 0.30$
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, $M = -6.8036747E-011$
Shear Force, $V_2 = -3853.513$
Shear Force, $V_3 = 3.4695601E-014$
Axial Force, $F = -4772.994$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 2676.637$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1137.257$

-Compression: $A_{sl,com} = 1137.257$

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

Mean Diameter of Tension Reinforcement, $DbL = 16.80$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{R} = u = 0.00692703$

$u = y + p = 0.00692703$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00692703$ ((4.29), Biskinis Phd))

$M_y = 5.6875E+007$

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

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

factor = 0.30

$A_g = 125000.00$

$f_c' = 20.00$

$N = 4772.994$

$E_c * I_g = 1.3684E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$y_{ten} = 9.2393283E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 248.9644$

$d = 208.00$

$y = 0.35225571$

$A = 0.02592123$

$B = 0.01565122$

with $p_t = 0.01093516$

$p_c = 0.01093516$

$p_v = 0.00386658$

$N = 4772.994$

$b = 500.00$

" = 0.20192308

$y_{comp} = 2.3973960E-005$

with $f_c' (12.3, (ACI 440)) = 20.44353$

$f_c = 20.00$

$f_l = 0.9425867$

$b = 500.00$

$h = 250.00$

$A_g = 125000.00$

From (12.9), ACI 440: $k_a = 0.15009543$

$g = p_t + p_c + p_v = 0.02573689$

$r_c = 40.00$

$A_e / A_c = 0.60038173$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 21019.039$

$y = 0.35108518$

$A = 0.02560582$

$B = 0.01546688$

with $E_s = 200000.00$

Calculation of ratio I_b / I_d

Inadequate Lap Length with $l_b/l_d = 0.30$

- Calculation of ρ -

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

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
shear control ratio $V_{yE}/V_{CoIE} = 0.1467291$

$d = 208.00$

$s = 0.00$

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

$A_v = 157.0796$, 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.

$N_{UD} = 4772.994$

$A_g = 125000.00$

$f_{cE} = 20.00$

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

$\rho_l = \text{Area_Tot_Long_Rein}/(b*d) = 0.02573689$

$b = 500.00$

$d = 208.00$

$f_{cE} = 20.00$

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

At local axis: 2

Integration Section: (a)

Calculation No. 3

column C1, Floor 1

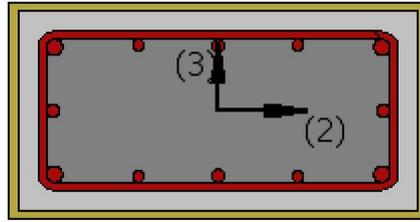
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity 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, $\gamma = 1.00$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = l_b/l_d = 0.30$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -6.8036747E-011$

Shear Force, $V_a = 3.4695601E-014$

EDGE -B-

Bending Moment, $M_b = -3.6047496E-011$

Shear Force, $V_b = -3.4695601E-014$
 BOTH EDGES
 Axial Force, $F = -4772.994$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 0.00$
 -Compression: $As_c = 2676.637$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{t,ten} = 1137.257$
 -Compression: $As_{c,com} = 1137.257$
 -Middle: $As_{mid} = 402.1239$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 330379.134$
 V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoL} = 330379.134$
 $V_{CoL} = 330379.134$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.00$

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

= 1 (normal-weight concrete)
 $f'_c = 16.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 6.8036747E-011$
 $V_u = 3.4695601E-014$
 $d = 0.8 \cdot h = 200.00$
 $N_u = 4772.994$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 125663.706$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$

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

V_f ((11-3)-(11.4), ACI 440) = 109599.773

$\phi = 0.95$, for fully-wrapped sections

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

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

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 208.00

ϕ_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$\phi_{fe} = 0.004$, from (11.6a), ACI 440

with $\phi_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 265721.532$

$b_w = 500.00$

$displacement_ductility_demand$ is calculated as ϕ / y

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

From analysis, chord rotation $\phi = 1.6615983E-022$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00692703$ ((4.29), Biskinis Phd)

$M_y = 5.6875E+007$

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

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

factor = 0.30

$A_g = 125000.00$

$f_c' = 20.00$

$N = 4772.994$

$E_c * I_g = 1.3684E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$y_{ten} = 9.2393283E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 248.9644$

$d = 208.00$

$y = 0.35225571$

$A = 0.02592123$

$B = 0.01565122$

with $pt = 0.01093516$

$pc = 0.01093516$

$pv = 0.00386658$

$N = 4772.994$

$b = 500.00$

" = 0.20192308

$y_{comp} = 2.3973960E-005$

with $f_c' (12.3, (ACI 440)) = 20.44353$

$f_c = 20.00$

$fl = 0.9425867$

$b = 500.00$

$h = 250.00$

$A_g = 125000.00$

From (12.9), ACI 440: $k_a = 0.15009543$

$g = pt + pc + pv = 0.02573689$

$rc = 40.00$

$A_e / A_c = 0.60038173$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 21019.039$

$y = 0.35108518$

$A = 0.02560582$

$B = 0.01546688$

with $E_s = 200000.00$

Calculation of ratio I_b / I_d

Inadequate Lap Length with $I_b / I_d = 0.30$

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

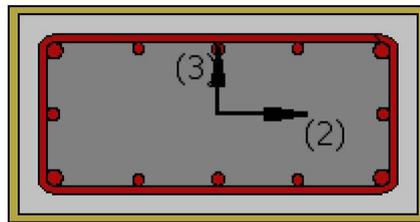
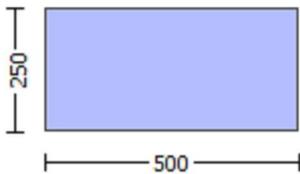
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: Start

Local Axis: (3)



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

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{o,min} = 0.30$

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, $V_a = -3.6206709E-031$

EDGE -B-

Shear Force, $V_b = 3.6206709E-031$

BOTH EDGES

Axial Force, $F = -4716.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_{lt} = 0.00$

-Compression: $As_{lc} = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{l,ten} = 1137.257$

-Compression: $As_{l,com} = 1137.257$

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

Calculation of Shear Capacity ratio, $V_e/V_r = 0.1467291$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 52248.951$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 7.8373E+007$

$Mu_{1+} = 7.8373E+007$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 7.8373E+007$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 7.8373E+007$

$Mu_{2+} = 7.8373E+007$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$Mu_{2-} = 7.8373E+007$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu_{1+}

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

$\phi_u = 3.3776478E-005$

$Mu = 7.8373E+007$

with full section properties:

$b = 500.00$

$d = 208.00$

$d' = 42.00$

$v = 0.0022677$

$N = 4716.808$

$f_c = 20.00$

ϕ_o (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_o) = 0.01470636$

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

From (5.4b), TBDY: $\phi_u = 0.01470636$

ϕ_u ((5.4c), TBDY) = $\phi_u^* * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_u, \phi_o) = 0.07848902$

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

$$fx = 0.07705054$$

$$af = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$bw = 500.00$$

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

$$fy = 0.12936483$$

$$af = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$bw = 250.00$$

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

$$R = 40.00$$

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

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

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

$$bo = 440.00$$

$$ho = 190.00$$

$$bi2 = 459400.00$$

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

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)

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

$$Ash = Astir*ns = 78.53982$$

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

$$bk = 500.00$$

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

$$Ash = Astir*ns = 78.53982$$

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

$$bk = 250.00$$

$$s = 100.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

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

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

$$y1 = 0.00129669$$

$$sh1 = 0.0044814$$

$$ft1 = 373.4467$$

$$fy1 = 311.2056$$

$$su1 = 0.00512$$

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

$$lo/lou,min = lb/ld = 0.30$$

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

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

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

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

$$\text{with } fs1 = fs = 311.2056$$

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

$$y2 = 0.00129669$$

$$sh2 = 0.0044814$$

$$ft2 = 373.4467$$

$$fy2 = 311.2056$$

$$su2 = 0.00512$$

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

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669

shv = 0.0044814

ftv = 373.4467

fyv = 311.2056

suv = 0.00512

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

lo/lou,min = lb/ld = 0.30

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 = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17015411

2 = Asl,com/(b*d)*(fs2/fc) = 0.17015411

v = Asl,mid/(b*d)*(fsv/fc) = 0.06016499

and confined core properties:

b = 440.00

d = 178.00

d' = 12.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = Asl,ten/(b*d)*(fs1/fc) = 0.22594519

2 = Asl,com/(b*d)*(fs2/fc) = 0.22594519

v = Asl,mid/(b*d)*(fsv/fc) = 0.07989222

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.27122702

Mu = MRc (4.14) = 7.8373E+007

u = su (4.1) = 3.3776478E-005

Calculation of ratio lb/ld

Inadequate Lap Length with lb/ld = 0.30

Calculation of Mu1-

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

u = 3.3776478E-005

Mu = 7.8373E+007

with full section properties:

b = 500.00

d = 208.00

d' = 42.00

v = 0.0022677

N = 4716.808

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01470636$

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

From (5.4b), TBDY: $cu = 0.01470636$

we ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.07848902$

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

fx = 0.07705054

af = 0.45253333

b = 500.00

h = 250.00

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

bw = 500.00

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

fy = 0.12936483

af = 0.45253333

b = 250.00

h = 500.00

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

bw = 250.00

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

R = 40.00

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

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = 0.05494666

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 = 555.55

fce = 20.00

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

c = confinement factor = 1.13916

y1 = 0.00129669

sh1 = 0.0044814

ft1 = 373.4467

fy1 = 311.2056

su1 = 0.00512

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

lo/lou,min = $lb/d = 0.30$

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

with $fs1 = fs = 311.2056$

with $Es1 = Es = 200000.00$

$y2 = 0.00129669$

$sh2 = 0.0044814$

$ft2 = 373.4467$

$fy2 = 311.2056$

$su2 = 0.00512$

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

$lo/lo_{min} = lb/lb_{min} = 0.30$

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

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

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

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

with $fs2 = fs = 311.2056$

with $Es2 = Es = 200000.00$

$yv = 0.00129669$

$shv = 0.0044814$

$ftv = 373.4467$

$fyv = 311.2056$

$suv = 0.00512$

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

$lo/lo_{min} = lb/ld = 0.30$

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

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

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

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

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

with $fsv = fs = 311.2056$

with $Esv = Es = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (fs1/fc) = 0.17015411$

2 = $Asl_{com}/(b \cdot d) \cdot (fs2/fc) = 0.17015411$

v = $Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.06016499$

and confined core properties:

$b = 440.00$

$d = 178.00$

$d' = 12.00$

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

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = $Asl_{ten}/(b \cdot d) \cdot (fs1/fc) = 0.22594519$

2 = $Asl_{com}/(b \cdot d) \cdot (fs2/fc) = 0.22594519$

v = $Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.07989222$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.27122702

$\mu_u = MR_c$ (4.14) = 7.8373E+007

$u = su$ (4.1) = 3.3776478E-005

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Mu2+

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

$$\mu = 3.3776478E-005$$

$$\text{Mu} = 7.8373E+007$$

with full section properties:

$$b = 500.00$$

$$d = 208.00$$

$$d' = 42.00$$

$$v = 0.0022677$$

$$N = 4716.808$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_o) = 0.01470636$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01470636$$

$$\mu_{we} \text{ ((5.4c), TBDY)} = a_{se} * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$$

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

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$b_w = 500.00$$

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

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

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

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)

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

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

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

$$b_k = 500.00$$

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

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

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

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00129669$$

$sh1 = 0.0044814$
 $ft1 = 373.4467$
 $fy1 = 311.2056$
 $su1 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.30$
 $su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$
 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 $fs1 = fs = 311.2056$
 with $Es1 = Es = 200000.00$
 $y2 = 0.00129669$
 $sh2 = 0.0044814$
 $ft2 = 373.4467$
 $fy2 = 311.2056$
 $su2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/lb,min = 0.30$
 $su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$
 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 $fs2 = fs = 311.2056$
 with $Es2 = Es = 200000.00$
 $yv = 0.00129669$
 $shv = 0.0044814$
 $ftv = 373.4467$
 $fyv = 311.2056$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.30$
 $suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$
 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 $fsv = fs = 311.2056$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.17015411$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.17015411$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.06016499$
 and confined core properties:
 $b = 440.00$
 $d = 178.00$
 $d' = 12.00$
 $fcc (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.22594519$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.22594519$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.07989222$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs,y2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.27122702$

$$\begin{aligned} \text{Mu} &= \text{MRc} (4.14) = 7.8373\text{E}+007 \\ u &= \text{su} (4.1) = 3.3776478\text{E}-005 \end{aligned}$$

Calculation of ratio I_b/I_d

Inadequate Lap Length with $I_b/I_d = 0.30$

Calculation of Mu_2

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

$$\begin{aligned} u &= 3.3776478\text{E}-005 \\ \text{Mu} &= 7.8373\text{E}+007 \end{aligned}$$

with full section properties:

$$\begin{aligned} b &= 500.00 \\ d &= 208.00 \\ d' &= 42.00 \\ v &= 0.0022677 \\ N &= 4716.808 \\ f_c &= 20.00 \\ c_o (5A.5, \text{TBDY}) &= 0.002 \\ \text{Final value of } \phi_u: \phi_u^* &= \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01470636 \\ \text{The Shear_factor is considered equal to 1 (pure moment strength)} \\ \text{From (5.4b), TBDY: } \phi_u &= 0.01470636 \\ \phi_{we} ((5.4c), \text{TBDY}) &= a_{se} * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07848902 \\ \text{where } \phi &= a_f * p_f * f_{fe} / f_{ce} \text{ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)} \end{aligned}$$

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

$$\begin{aligned} \phi_y &= 0.12936483 \\ a_f &= 0.45253333 \\ b &= 250.00 \\ h &= 500.00 \\ \text{From EC8 A.4.4.3(6), } p_f &= 2t_f/b_w = 0.008128 \\ b_w &= 250.00 \\ \text{effective stress from (A.35), } f_{f,e} &= 703.4155 \end{aligned}$$

$$\begin{aligned} R &= 40.00 \\ \text{Effective FRP thickness, } t_f &= NL * t * \text{Cos}(b_1) = 1.016 \\ f_{u,f} &= 1055.00 \\ E_f &= 64828.00 \\ u_{,f} &= 0.015 \\ a_{se} ((5.4d), \text{TBDY}) &= 0.05494666 \\ b_o &= 440.00 \\ h_o &= 190.00 \\ b_{i2} &= 459400.00 \\ p_{sh,min} &= \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159 \end{aligned}$$

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)

$$\begin{aligned} p_{sh,x} (5.4d) &= 0.00314159 \\ A_{sh} &= A_{stir} * n_s = 78.53982 \\ \text{No stirrups, } n_s &= 2.00 \\ b_k &= 500.00 \end{aligned}$$

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

Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 555.55
fce = 20.00

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

y1 = 0.00129669
sh1 = 0.0044814
ft1 = 373.4467
fy1 = 311.2056
su1 = 0.00512

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

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669
sh2 = 0.0044814
ft2 = 373.4467
fy2 = 311.2056
su2 = 0.00512

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

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669
shv = 0.0044814
ftv = 373.4467
fyv = 311.2056
suv = 0.00512

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

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17015411

2 = Asl,com/(b*d)*(fs2/fc) = 0.17015411

v = Asl,mid/(b*d)*(fsv/fc) = 0.06016499

and confined core properties:

b = 440.00
d = 178.00
d' = 12.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22594519$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.22594519$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07989222$$

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

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

$$\text{su (4.9)} = 0.27122702$$

$$\text{Mu} = \text{MRc (4.14)} = 7.8373\text{E}+007$$

$$u = \text{su (4.1)} = 3.3776478\text{E}-005$$

Calculation of ratio lb/l_d

Inadequate Lap Length with lb/l_d = 0.30

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 356091.268$

Calculation of Shear Strength at edge 1, $V_{r1} = 356091.268$

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

$$V_{Col0} = 356091.268$$

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

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

= 1 (normal-weight concrete)

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

$M/Vd = 2.00$

$$\text{Mu} = 6.4608054\text{E}-012$$

$$\text{Vu} = 3.6206709\text{E}-031$$

$$d = 0.8 * h = 200.00$$

$$\text{Nu} = 4716.808$$

$$\text{Ag} = 125000.00$$

From (11.5.4.8), ACI 318-14: $V_s = 139624.944$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 100.00$$

V_s is multiplied by $Col = 1.00$

$$s/d = 0.50$$

V_f ((11-3)-(11.4), ACI 440) = 109599.773

$f = 0.95$, 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: $\alpha = 90^\circ = 90.00$

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 208.00

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: $V_s + V_f \leq 297085.704$

$$b_w = 500.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 356091.268$

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

$$V_{Col0} = 356091.268$$

kn1 = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)

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

$M/Vd = 2.00$

$\mu_u = 6.4608054E-012$

$\nu_u = 3.6206709E-031$

$d = 0.8 \cdot h = 200.00$

$N_u = 4716.808$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 139624.944$

$A_v = 157079.633$

$f_y = 444.44$

$s = 100.00$

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

$s/d = 0.50$

V_f ((11-3)-(11.4), ACI 440) = 109599.773

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 208.00

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

$E_f = 64828.00$

$f_{e} = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$

$b_w = 500.00$

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

At local axis: 3

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

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcrcs

Constant Properties

Knowledge Factor, $\phi = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

Element Length, L = 3000.00
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
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, $V_a = 8.5800179E-032$
EDGE -B-
Shear Force, $V_b = -8.5800179E-032$
BOTH EDGES
Axial Force, F = -4716.808
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 2676.637$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten} = 829.3805$
-Compression: $A_{st,com} = 829.3805$
-Middle: $A_{st,mid} = 1017.876$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.27523624$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 112690.591$
with
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 1.6904E+008$
 $\mu_{1+} = 1.6904E+008$, 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
 $\mu_{1-} = 1.6904E+008$, 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
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 1.6904E+008$
 $\mu_{2+} = 1.6904E+008$, 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
 $\mu_{2-} = 1.6904E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment
direction which is defined for the the static loading combination

Calculation of μ_{1+}

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

$$\mu = 1.4516822E-005$$

$$M_u = 1.6904E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$d' = 43.00$

$v = 0.00206425$

$N = 4716.808$

$fc = 20.00$

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

Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01470636$

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

From (5.4b), TBDY: $cu = 0.01470636$

we ((5.4c), TBDY) = $ase * sh_{,min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.07848902$

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

 $fx = 0.07705054$

$af = 0.45253333$

$b = 500.00$

$h = 250.00$

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

$bw = 500.00$

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

 $fy = 0.12936483$

$af = 0.45253333$

$b = 250.00$

$h = 500.00$

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

$bw = 250.00$

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

 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase ((5.4d), TBDY) = 0.05494666$

$bo = 440.00$

$ho = 190.00$

$bi2 = 459400.00$

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

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)

 $psh_{,x} (5.4d) = 0.00314159$

$Ash = Astir * ns = 78.53982$

No stirrups, $ns = 2.00$

$bk = 500.00$

 $psh_{,y} (5.4d) = 0.00628319$

$Ash = Astir * ns = 78.53982$

No stirrups, $ns = 2.00$

$bk = 250.00$

 $s = 100.00$

$fy_{we} = 555.55$

$f_{ce} = 20.00$

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

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

$y1 = 0.00129669$

$sh1 = 0.0044814$

$ft1 = 373.4467$

$fy1 = 311.2056$

$su1 = 0.00512$

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

$lo/lou_{,min} = lb/d = 0.30$

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

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

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered

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

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

with $f_{s1} = f_s = 311.2056$

with $E_{s1} = E_s = 200000.00$

$y_2 = 0.00129669$

$sh_2 = 0.0044814$

$ft_2 = 373.4467$

$fy_2 = 311.2056$

$su_2 = 0.00512$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$

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

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 $f_{s2} = f_s = 311.2056$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.00129669$

$sh_v = 0.0044814$

$ft_v = 373.4467$

$fy_v = 311.2056$

$su_v = 0.00512$

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

$l_o/l_{o,min} = l_b/l_d = 0.30$

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

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 $f_{sv} = f_s = 311.2056$

with $E_{sv} = E_s = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.11295746$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.11295746$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.13862961$

and confined core properties:

$b = 190.00$

$d = 427.00$

$d' = 13.00$

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

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

c = confinement factor = 1.13916

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.15907051$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.15907051$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.19522289$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.2282401$

$\mu_u = MR_c (4.14) = 1.6904E+008$

u = $su (4.1) = 1.4516822E-005$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{u1} -

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

$$u = 1.4516822E-005$$

$$\mu = 1.6904E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00206425$$

$$N = 4716.808$$

$$f_c = 20.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01470636$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.01470636$$

$$\omega_{we} \text{ ((5.4c), TBDY)} = \alpha_{se} * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07848902$$

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

$$\phi_x = 0.07705054$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$bw = 500.00$$

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

$$\phi_y = 0.12936483$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$bw = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

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

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

$$\text{psh}_{,x} \text{ (5.4d)} = 0.00314159$$

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

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

$$b_k = 500.00$$

$$\text{psh}_{,y} \text{ (5.4d)} = 0.00628319$$

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

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

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00129669$$

$$\text{sh}_1 = 0.0044814$$

$$ft1 = 373.4467$$

$$fy1 = 311.2056$$

$$su1 = 0.00512$$

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

$$lo/lou,min = lb/d = 0.30$$

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

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

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

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

$$\text{with } fs1 = fs = 311.2056$$

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

$$y2 = 0.00129669$$

$$sh2 = 0.0044814$$

$$ft2 = 373.4467$$

$$fy2 = 311.2056$$

$$su2 = 0.00512$$

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

$$lo/lou,min = lb/lb,min = 0.30$$

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

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

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

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

$$\text{with } fs2 = fs = 311.2056$$

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

$$yv = 0.00129669$$

$$shv = 0.0044814$$

$$ftv = 373.4467$$

$$fyv = 311.2056$$

$$suv = 0.00512$$

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

$$lo/lou,min = lb/d = 0.30$$

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

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

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

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

$$\text{with } fsv = fs = 311.2056$$

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.11295746$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.11295746$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.13862961$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

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

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

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.15907051$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.15907051$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.19522289$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su (4.9) = 0.2282401$$

$$Mu = MRc (4.14) = 1.6904E+008$$

$$u = s_u(4.1) = 1.4516822E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{2+}

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

$$u = 1.4516822E-005$$

$$\mu = 1.6904E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00206425$$

$$N = 4716.808$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01470636$$

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

$$\text{From (5.4b), TBDY: } \mu_c = 0.01470636$$

$$\mu_{cc} \text{ ((5.4c), TBDY) } = \alpha s_e \cdot \text{sh}_{\min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$$

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

$$f_x = 0.07705054$$

$$\alpha f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$b_w = 500.00$$

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

$$f_y = 0.12936483$$

$$\alpha f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

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

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

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

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)

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

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

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

$$b_k = 500.00$$

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

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

No stirrups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 555.55
fce = 20.00

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

y1 = 0.00129669
sh1 = 0.0044814
ft1 = 373.4467
fy1 = 311.2056
su1 = 0.00512

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

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669
sh2 = 0.0044814
ft2 = 373.4467
fy2 = 311.2056
su2 = 0.00512

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

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669
shv = 0.0044814
ftv = 373.4467
fyv = 311.2056
suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11295746

2 = Asl,com/(b*d)*(fs2/fc) = 0.11295746

v = Asl,mid/(b*d)*(fsv/fc) = 0.13862961

and confined core properties:

b = 190.00
d = 427.00
d' = 13.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.15907051$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.15907051$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.19522289$$

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

--->

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

--->

$$s_u(4.9) = 0.2282401$$

$$\mu_u = M_{Rc}(4.14) = 1.6904E+008$$

$$u = s_u(4.1) = 1.4516822E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{u2}

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

$$u = 1.4516822E-005$$

$$\mu_u = 1.6904E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00206425$$

$$N = 4716.808$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu_{cu}: \mu_{cu}^* = \text{shear_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.01470636$$

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

$$\text{From (5.4b), TBDY: } \mu_{cu} = 0.01470636$$

$$\mu_{we}((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$$

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

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$b_w = 500.00$$

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

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

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

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 = 555.55
fce = 20.00

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

y1 = 0.00129669
sh1 = 0.0044814
ft1 = 373.4467
fy1 = 311.2056
su1 = 0.00512

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

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669
sh2 = 0.0044814
ft2 = 373.4467
fy2 = 311.2056
su2 = 0.00512

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

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669
shv = 0.0044814
ftv = 373.4467
fyv = 311.2056
suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Esv = Es = 200000.00

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.11295746$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11295746$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.13862961$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

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

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

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.15907051$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.15907051$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.19522289$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.2282401$$

$$\mu_u = M R_c (4.14) = 1.6904E+008$$

$$u = s_u (4.1) = 1.4516822E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 409432.244$

Calculation of Shear Strength at edge 1, $V_{r1} = 409432.244$

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

$$V_{Col0} = 409432.244$$

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

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).

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

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

$$M/Vd = 2.00$$

$$\mu_u = 8.5689464E-013$$

$$V_u = 8.5800179E-032$$

$$d = 0.8 * h = 400.00$$

$$N_u = 4716.808$$

$$A_g = 125000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 279249.888$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 100.00$$

$$V_s \text{ is multiplied by } C_{ol} = 1.00$$

$$s/d = 0.25$$

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

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

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

In (11.3) $\sin + \cos$ 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.

$$\text{orientation 1: } \theta = b_1 + 90^\circ = 90.00$$

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

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

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

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

$$E_f = 64828.00$$

$f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 409432.244$
 $V_{r2} = V_{CoI} ((10.3), ASCE 41-17) = k_{nl} * V_{CoI0}$
 $V_{CoI0} = 409432.244$
 $k_{nl} = 1$ (zero step-static loading)

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

 $= 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M / Vd = 2.00$
 $\mu_u = 8.5689464E-013$
 $V_u = 8.5800179E-032$
 $d = 0.8 * h = 400.00$
 $N_u = 4716.808$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 279249.888$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 100.00$

V_s is multiplied by $CoI = 1.00$
 $s/d = 0.25$

$V_f ((11-3)-(11.4), ACI 440) = 240803.347$
 $f = 0.95$, 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, $t_{f1} = N_L * t / N_{oDir} = 1.016$

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $b_w = 250.00$

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

At local axis: 2

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

At local axis: 3

Integration Section: (a)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$
Section Height, $H = 250.00$
Section Width, $W = 500.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_b/l_d = 0.30$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -1.1597E+007$
Shear Force, $V_2 = -3853.513$
Shear Force, $V_3 = 3.4695601E-014$
Axial Force, $F = -4772.994$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 2676.637$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten} = 829.3805$
-Compression: $A_{sc,com} = 829.3805$
-Middle: $A_{st,mid} = 1017.876$
Mean Diameter of Tension Reinforcement, $DbL = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{R} = * u = 0.00698058$
 $u = y + p = 0.00698058$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00698058$ ((4.29), Biskinis Phd)
 $M_y = 1.1427E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3009.429
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.6421E+013$
factor = 0.30
 $A_g = 125000.00$
 $f_c' = 20.00$
 $N = 4772.994$
 $E_c * I_g = 5.4737E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.0111358E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b/l_d)^{2/3}) = 248.9644$

$d = 457.00$
 $y = 0.3209156$
 $A = 0.0235957$
 $B = 0.01298394$
 with $pt = 0.00725935$
 $pc = 0.00725935$
 $pv = 0.0089092$
 $N = 4772.994$
 $b = 250.00$
 $\rho = 0.0940919$
 $y_{comp} = 1.1987390E-005$
 with $f_c^* (12.3, (ACI 440)) = 20.44423$
 $f_c = 20.00$
 $f_l = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $A_g = 125000.00$
 From (12.9), ACI 440: $k_a = 0.15033165$
 $g = pt + pc + pv = 0.02342789$
 $rc = 40.00$
 $A_e/A_c = 0.60132659$
 Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.31958736$
 $A = 0.02330859$
 $B = 0.01281613$
 with $E_s = 200000.00$

 Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

- Calculation of ρ -

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

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
 shear control ratio $V_y E / V_{col} E = 0.27523624$

$d = 457.00$

$s = 0.00$

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

$A_v = 157.0796$, 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.

$N_{UD} = 4772.994$

$A_g = 125000.00$

$f_{cE} = 20.00$

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

$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.02342789$

$b = 250.00$

$d = 457.00$

$f_{cE} = 20.00$

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

At local axis: 3

Integration Section: (a)

Calculation No. 5

column C1, Floor 1

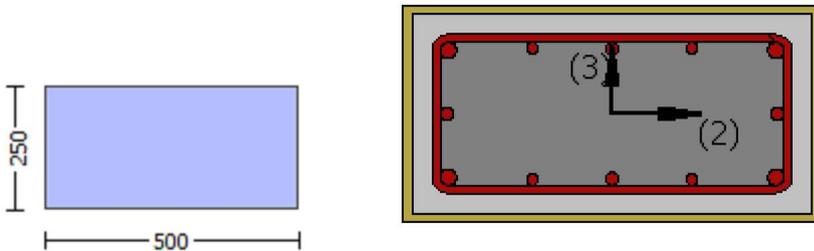
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (2)



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

At local axis: 2

Integration Section: (b)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou,min} = l_b/d = 0.30$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $N_{oDir} = 1$
 Fiber orientations, $b_i = 0.00^\circ$
 Number of layers, $N_L = 1$
 Radius of rounding corners, $R = 40.00$

 Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = -1.1597E+007$
 Shear Force, $V_a = -3853.513$
 EDGE -B-
 Bending Moment, $M_b = 33515.919$
 Shear Force, $V_b = 3853.513$
 BOTH EDGES
 Axial Force, $F = -4772.994$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{sl,t} = 0.00$
 -Compression: $A_{sl,c} = 2676.637$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{sl,ten} = 829.3805$
 -Compression: $A_{sl,com} = 829.3805$
 -Middle: $A_{sl,mid} = 1017.876$
 Mean Diameter of Tension Reinforcement, $D_{bL,ten} = 18.66667$

 Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 366317.176$
 $V_n ((10.3), ASCE 41-17) = k_n \phi V_{CoI} = 366317.176$
 $V_{CoI} = 366317.176$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.15300225$

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

 $\phi = 1$ (normal-weight concrete)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 33515.919$
 $V_u = 3853.513$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4772.994$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 251327.412$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 V_s is multiplied by $\phi_{CoI} = 1.00$
 $s/d = 0.25$
 $V_f ((11-3)-(11.4), ACI 440) = 240803.347$
 $\phi = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).

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

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

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

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

$d_{fv} = d$ (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: $V_s + V_f \leq 265721.532$

$b_w = 250.00$

displacement ductility demand is calculated as δ / y

- Calculation of δ / y for END B -

for rotation axis 3 and integ. section (b)

From analysis, chord rotation $\theta = 0.00010647$

$y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00069587$ ((4.29), Biskinis Phd)

$M_y = 1.1427E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00

From table 10.5, ASCE 41_17: $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 1.6421E+013$

factor = 0.30

$A_g = 125000.00$

$f_c' = 20.00$

$N = 4772.994$

$E_c \cdot I_g = 5.4737E+013$

Calculation of Yielding Moment M_y

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

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

$y_{\text{ten}} = 4.0111358E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 248.9644$

$d = 457.00$

$y = 0.3209156$

$A = 0.0235957$

$B = 0.01298394$

with $p_t = 0.00725935$

$p_c = 0.00725935$

$p_v = 0.0089092$

$N = 4772.994$

$b = 250.00$

$\alpha = 0.0940919$

$y_{\text{comp}} = 1.1987390E-005$

with f_c^* (12.3, (ACI 440)) = 20.44423

$f_c = 20.00$

$f_l = 0.9425867$

$b = 250.00$

$h = 500.00$

$A_g = 125000.00$

From (12.9), ACI 440: $k_a = 0.15033165$

$g = p_t + p_c + p_v = 0.02342789$

$r_c = 40.00$

$A_e / A_c = 0.60132659$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 21019.039$

$y = 0.31958736$

A = 0.02330859
B = 0.01281613
with $E_s = 200000.00$

Calculation of ratio I_b/I_d

Inadequate Lap Length with $I_b/I_d = 0.30$

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

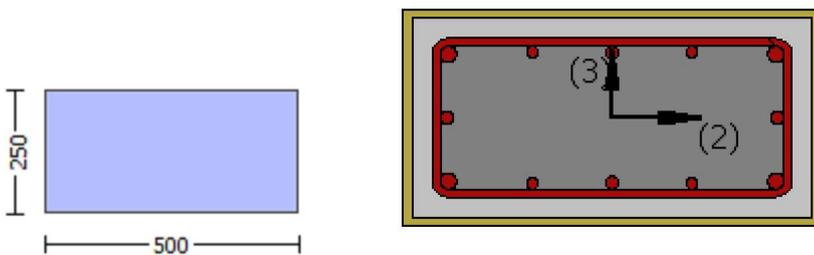
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: End

Local Axis: (2)



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

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou, \min} = 0.30$

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, $V_a = -3.6206709E-031$

EDGE -B-

Shear Force, $V_b = 3.6206709E-031$

BOTH EDGES

Axial Force, $F = -4716.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl} = 0.00$

-Compression: $A_{slc} = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl, \text{ten}} = 1137.257$

-Compression: $A_{sl, \text{com}} = 1137.257$

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

Calculation of Shear Capacity ratio , $V_e/V_r = 0.1467291$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 52248.951$

with

$M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 7.8373E+007$

$M_{u1+} = 7.8373E+007$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 7.8373E+007$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 7.8373E+007$

$M_{u2+} = 7.8373E+007$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 7.8373E+007$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of M_{u1+}

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

$$\kappa_u = 3.3776478E-005$$

$$M_u = 7.8373E+007$$

with full section properties:

$$b = 500.00$$

$$d = 208.00$$

$$d' = 42.00$$

$$v = 0.0022677$$

$$N = 4716.808$$

$$f_c = 20.00$$

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

$$\text{Final value of } \kappa_u: \kappa_u^* = \text{shear_factor} * \text{Max}(\kappa_u, \kappa_c) = 0.01470636$$

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

$$\text{From (5.4b), TBDY: } \kappa_u = 0.01470636$$

$$\omega_{we} \text{ ((5.4c), TBDY)} = \alpha_{se} * \text{sh}_{, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$$

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

$$f_x = 0.07705054$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$b_w = 500.00$$

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

$$f_y = 0.12936483$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

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

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

$$\text{psh}_x \text{ (5.4d)} = 0.00314159$$

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

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

$$b_k = 500.00$$

$$\text{psh}_y \text{ (5.4d)} = 0.00628319$$

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

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

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00129669$$

$$\text{sh}_1 = 0.0044814$$

$$f_{t1} = 373.4467$$

$f_{y1} = 311.2056$
 $s_{u1} = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30$
 $s_{u1} = 0.4 * e_{s1_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{s1_nominal} = 0.08$,
 For calculation of $e_{s1_nominal}$ and y_1, sh_1, ft_1, f_{y1} , it is considered
 characteristic value $f_{sy1} = f_{s1}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s1} = f_s = 311.2056$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.00129669$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4467$
 $f_{y2} = 311.2056$
 $s_{u2} = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$
 $s_{u2} = 0.4 * e_{s2_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{s2_nominal} = 0.08$,
 For calculation of $e_{s2_nominal}$ and y_2, sh_2, ft_2, f_{y2} , it is considered
 characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.
 y_2, sh_2, ft_2, f_{y2} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 311.2056$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00129669$
 $sh_v = 0.0044814$
 $ft_v = 373.4467$
 $f_{yv} = 311.2056$
 $s_{uv} = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30$
 $s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{suv_nominal} = 0.08$,
 considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $e_{suv_nominal}$ and y_v, sh_v, ft_v, f_{yv} , 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.
 with $f_{sv} = f_s = 311.2056$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.17015411$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.17015411$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.06016499$
 and confined core properties:
 $b = 440.00$
 $d = 178.00$
 $d' = 12.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22594519$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.22594519$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07989222$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $s_u (4.9) = 0.27122702$
 $M_u = M_{Rc} (4.14) = 7.8373E+007$
 $u = s_u (4.1) = 3.3776478E-005$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{u1}

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

$$\mu_u = 3.3776478E-005$$

$$\mu_{u1} = 7.8373E+007$$

with full section properties:

$$b = 500.00$$

$$d = 208.00$$

$$d' = 42.00$$

$$v = 0.0022677$$

$$N = 4716.808$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu_{cu}: \mu_{cu}^* = \text{shear_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.01470636$$

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

$$\text{From (5.4b), TBDY: } \mu_{cu} = 0.01470636$$

$$\mu_{we} \text{ ((5.4c), TBDY)} = \alpha_{se} * \text{sh}_{,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$$

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

$$f_x = 0.07705054$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$bw = 500.00$$

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

$$f_y = 0.12936483$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$bw = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

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

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

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

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

$$\text{psh}_x \text{ (5.4d)} = 0.00314159$$

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

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

$$b_k = 500.00$$

$$\text{psh}_y \text{ (5.4d)} = 0.00628319$$

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

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

bk = 250.00

s = 100.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.13916

y1 = 0.00129669

sh1 = 0.0044814

ft1 = 373.4467

fy1 = 311.2056

su1 = 0.00512

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

lo/lou,min = lb/ld = 0.30

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

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

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

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

with fs1 = fs = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669

sh2 = 0.0044814

ft2 = 373.4467

fy2 = 311.2056

su2 = 0.00512

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

lo/lou,min = lb/lb,min = 0.30

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

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

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

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

with fs2 = fs = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669

shv = 0.0044814

ftv = 373.4467

fyv = 311.2056

suv = 0.00512

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

lo/lou,min = lb/ld = 0.30

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

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

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

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

with fsv = fs = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17015411

2 = Asl,com/(b*d)*(fs2/fc) = 0.17015411

v = Asl,mid/(b*d)*(fsv/fc) = 0.06016499

and confined core properties:

b = 440.00

d = 178.00

d' = 12.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = Asl,ten/(b*d)*(fs1/fc) = 0.22594519

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.22594519$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07989222$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

$$s_u(4.9) = 0.27122702$$

$$M_u = M_{Rc}(4.14) = 7.8373E+007$$

$$u = s_u(4.1) = 3.3776478E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u2+}

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

$$u = 3.3776478E-005$$

$$M_u = 7.8373E+007$$

with full section properties:

$$b = 500.00$$

$$d = 208.00$$

$$d' = 42.00$$

$$v = 0.0022677$$

$$N = 4716.808$$

$$f_c = 20.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01470636$$

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

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01470636$$

$$\phi_{cc} \text{ ((5.4c), TBDY) } = \alpha_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07848902$$

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

$$\phi_{fx} = 0.07705054$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$bw = 500.00$$

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

$$\phi_{fy} = 0.12936483$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$bw = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

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

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

earthquake detailing (90° closed stirrups)

psh,x (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 = 555.55
fce = 20.00

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

y1 = 0.00129669
sh1 = 0.0044814
ft1 = 373.4467
fy1 = 311.2056
su1 = 0.00512

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

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669
sh2 = 0.0044814
ft2 = 373.4467
fy2 = 311.2056
su2 = 0.00512

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

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669
shv = 0.0044814
ftv = 373.4467
fyv = 311.2056
suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17015411

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.17015411$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.06016499$$

and confined core properties:

$$b = 440.00$$

$$d = 178.00$$

$$d' = 12.00$$

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

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

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22594519$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.22594519$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07989222$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.27122702$$

$$M_u = M_{Rc} (4.14) = 7.8373E+007$$

$$u = s_u (4.1) = 3.3776478E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u2}

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

$$u = 3.3776478E-005$$

$$M_u = 7.8373E+007$$

with full section properties:

$$b = 500.00$$

$$d = 208.00$$

$$d' = 42.00$$

$$v = 0.0022677$$

$$N = 4716.808$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01470636$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01470636$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$$

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

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$b_w = 500.00$$

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

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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, $n_s = 2.00$

$b_k = 250.00$

 $s = 100.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

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

$y_1 = 0.00129669$

$sh_1 = 0.0044814$

$ft_1 = 373.4467$

$fy_1 = 311.2056$

$su_1 = 0.00512$

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

$l_o/l_{ou, min} = l_b/l_d = 0.30$

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

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 $fs_1 = fs = 311.2056$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00129669$

$sh_2 = 0.0044814$

$ft_2 = 373.4467$

$fy_2 = 311.2056$

$su_2 = 0.00512$

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

$l_o/l_{ou, min} = l_b/l_{b, min} = 0.30$

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

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 $fs_2 = fs = 311.2056$

with $Es_2 = Es = 200000.00$

$y_v = 0.00129669$

$sh_v = 0.0044814$

$ft_v = 373.4467$

$fy_v = 311.2056$

$su_v = 0.00512$

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

$$l_o/l_{o,min} = l_b/d = 0.30$$

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

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

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

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

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

$$\text{with } f_{sv} = f_s = 311.2056$$

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.17015411$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.17015411$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.06016499$$

and confined core properties:

$$b = 440.00$$

$$d = 178.00$$

$$d' = 12.00$$

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

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

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.22594519$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.22594519$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.07989222$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.27122702$$

$$M_u = M_{Rc} (4.14) = 7.8373E+007$$

$$u = s_u (4.1) = 3.3776478E-005$$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 356091.268$

Calculation of Shear Strength at edge 1, $V_{r1} = 356091.268$

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

$$V_{Col0} = 356091.268$$

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

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)

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

$$M/Vd = 2.00$$

$$M_u = 6.4608054E-012$$

$$V_u = 3.6206709E-031$$

$$d = 0.8 * h = 200.00$$

$$N_u = 4716.808$$

$$A_g = 125000.00$$

From (11.5.4.8), ACI 318-14: $V_s = 139624.944$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 100.00$$

V_s is multiplied by $Col = 1.00$

$$s/d = 0.50$$

$$V_f ((11-3)-(11.4), ACI 440) = 109599.773$$

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

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

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

$dfv = d$ (figure 11.2, ACI 440) = 208.00

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

$E_f = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$

$bw = 500.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 356091.268$

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

$V_{Col0} = 356091.268$

$knl = 1$ (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).

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

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

$M/d = 2.00$

$\mu_u = 6.4608054E-012$

$\nu_u = 3.6206709E-031$

$d = 0.8 * h = 200.00$

$N_u = 4716.808$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 139624.944$

$A_v = 157079.633$

$f_y = 444.44$

$s = 100.00$

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

$s/d = 0.50$

V_f ((11-3)-(11.4), ACI 440) = 109599.773

$f = 0.95$, 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 $(\cot \theta + \csc \theta) \sin a$ 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: $\theta = b1 + 90^\circ = 90.00$

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

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

$dfv = d$ (figure 11.2, ACI 440) = 208.00

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

$E_f = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$

$bw = 500.00$

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

At local axis: 3

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

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\phi = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$

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, $V_a = 8.5800179E-032$

EDGE -B-

Shear Force, $V_b = -8.5800179E-032$

BOTH EDGES

Axial Force, $F = -4716.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression: $A_{sl,c} = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

-Middle: $A_{sl,mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.27523624$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 112690.591$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.6904E+008$

$M_{u1+} = 1.6904E+008$, 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

$M_{u1-} = 1.6904E+008$, 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

$$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 1.6904E+008$$

$\mu_{2+} = 1.6904E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 1.6904E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of μ_{1+}

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

$$\mu_u = 1.4516822E-005$$

$$M_u = 1.6904E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00206425$$

$$N = 4716.808$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu_{cu} = \text{shear_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.01470636$$

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

$$\text{From (5.4b), TBDY: } \mu_{cu} = 0.01470636$$

$$\mu_{we} \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.07848902$$

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

$$\mu_{fx} = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$b_w = 500.00$$

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

$$\mu_{fy} = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(\beta_1) = 1.016$$

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

$$E_f = 64828.00$$

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

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

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

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

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

$$\mu_{psh,x} \text{ (5.4d)} = 0.00314159$$

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

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

$$b_k = 500.00$$

$$\mu_{psh,y} \text{ (5.4d)} = 0.00628319$$

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

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

$$b_k = 250.00$$

$s = 100.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$
 From ((5.A5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $y_1 = 0.00129669$
 $sh_1 = 0.0044814$
 $ft_1 = 373.4467$
 $fy_1 = 311.2056$
 $su_1 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/d = 0.30$
 $su_1 = 0.4 * esu_1 \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esu_1 \text{ nominal} = 0.08$,
 For calculation of $esu_1 \text{ nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 311.2056$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.00129669$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4467$
 $fy_2 = 311.2056$
 $su_2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/lb, \min = 0.30$
 $su_2 = 0.4 * esu_2 \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esu_2 \text{ nominal} = 0.08$,
 For calculation of $esu_2 \text{ nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 311.2056$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.00129669$
 $sh_v = 0.0044814$
 $ft_v = 373.4467$
 $fy_v = 311.2056$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/d = 0.30$
 $suv = 0.4 * esuv \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esuv \text{ nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv \text{ nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 311.2056$
 with $Esv = Es = 200000.00$
 $1 = Asl, \text{ten}/(b*d) * (fs_1/fc) = 0.11295746$
 $2 = Asl, \text{com}/(b*d) * (fs_2/fc) = 0.11295746$
 $v = Asl, \text{mid}/(b*d) * (fsv/fc) = 0.13862961$
 and confined core properties:
 $b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $f_{cc} \text{ (5A.2, TBDY)} = 22.78316$
 $cc \text{ (5A.5, TBDY)} = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl, \text{ten}/(b*d) * (fs_1/fc) = 0.15907051$
 $2 = Asl, \text{com}/(b*d) * (fs_2/fc) = 0.15907051$

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.19522289$$

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

--->

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

--->

$$s_u(4.9) = 0.2282401$$

$$\mu_u = M_{Rc}(4.14) = 1.6904E+008$$

$$u = s_u(4.1) = 1.4516822E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{u1} -

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

$$u = 1.4516822E-005$$

$$\mu_u = 1.6904E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00206425$$

$$N = 4716.808$$

$$f_c = 20.00$$

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

$$\text{Final value of } \alpha_{cu}: \alpha_{cu}^* = \text{shear_factor} \cdot \text{Max}(\alpha_{cu}, \alpha_{cc}) = 0.01470636$$

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

$$\text{From (5.4b), TBDY: } \alpha_{cu} = 0.01470636$$

$$\alpha_{we} \text{ ((5.4c), TBDY) } = \alpha_{se} \cdot \text{sh}_{, \min} \cdot f_{ywe} / f_{ce} + \text{Min}(\alpha_{fx}, \alpha_{fy}) = 0.07848902$$

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)

$$\alpha_{fx} = 0.07705054$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$b_w = 500.00$$

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

$$\alpha_{fy} = 0.12936483$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(\beta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

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

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 = 555.55
fce = 20.00

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

y1 = 0.00129669
sh1 = 0.0044814
ft1 = 373.4467
fy1 = 311.2056
su1 = 0.00512

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

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669
sh2 = 0.0044814
ft2 = 373.4467
fy2 = 311.2056
su2 = 0.00512

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

lo/lou,min = lb/lb,min = 0.30

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

with fs2 = fs = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669
shv = 0.0044814
ftv = 373.4467
fyv = 311.2056
suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11295746

2 = Asl,com/(b*d)*(fs2/fc) = 0.11295746

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.13862961$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

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

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

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.15907051$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.15907051$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.19522289$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.2282401$$

$$\mu_u = M_{Rc} (4.14) = 1.6904E+008$$

$$u = s_u (4.1) = 1.4516822E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{u2+}

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

$$u = 1.4516822E-005$$

$$\mu_u = 1.6904E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00206425$$

$$N = 4716.808$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01470636$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01470636$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$$

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

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$b_w = 500.00$$

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

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t^* \text{Cos}(\beta_1) = 1.016$$

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 = 555.55
fce = 20.00

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

y1 = 0.00129669
sh1 = 0.0044814
ft1 = 373.4467
fy1 = 311.2056
su1 = 0.00512

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

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669
sh2 = 0.0044814
ft2 = 373.4467
fy2 = 311.2056
su2 = 0.00512

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

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669
shv = 0.0044814
ftv = 373.4467
fyv = 311.2056
suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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

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 $fsv = fs = 311.2056$

with $Esv = Es = 200000.00$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.11295746$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.11295746$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.13862961$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

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

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

c = confinement factor = 1.13916

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.15907051$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.15907051$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.19522289$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su (4.9) = 0.2282401$$

$$Mu = MRc (4.14) = 1.6904E+008$$

$$u = su (4.1) = 1.4516822E-005$$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of $Mu2$ -

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

$$u = 1.4516822E-005$$

$$Mu = 1.6904E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00206425$$

$$N = 4716.808$$

$$fc = 20.00$$

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

Final value of cu : $cu^* = shear_factor * Max(cu, cc) = 0.01470636$

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

From (5.4b), TBDY: $cu = 0.01470636$

$$we ((5.4c), TBDY) = ase * sh,min * fywe / fce + Min(fx, fy) = 0.07848902$$

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

$$fx = 0.07705054$$

$$af = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$bw = 500.00$$

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

$f_y = 0.12936483$
 $a_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$
From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$
 $b_w = 250.00$
effective stress from (A.35), $f_{f,e} = 703.4155$

 $R = 40.00$
Effective FRP thickness, $t_f = NL*t*\cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $a_{se} \text{ ((5.4d), TBDY)} = 0.05494666$
 $b_o = 440.00$
 $h_o = 190.00$
 $b_{i2} = 459400.00$
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$

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, $n_s = 2.00$
 $b_k = 250.00$

 $s = 100.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$

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

$y_1 = 0.00129669$
 $sh_1 = 0.0044814$
 $ft_1 = 373.4467$
 $fy_1 = 311.2056$
 $su_1 = 0.00512$

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

$l_o/l_{ou,min} = l_b/l_d = 0.30$

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

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 $fs_1 = fs = 311.2056$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00129669$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4467$
 $fy_2 = 311.2056$
 $su_2 = 0.00512$

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

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$

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

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 $fs_2 = fs = 311.2056$

with $E_s = E_s = 200000.00$
 $y_v = 0.00129669$
 $sh_v = 0.0044814$
 $ft_v = 373.4467$
 $fy_v = 311.2056$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{u,min} = lb/ld = 0.30$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $fsv = fs = 311.2056$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.11295746$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.11295746$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.13862961$
 and confined core properties:
 $b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.15907051$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.15907051$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.19522289$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

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

$su (4.9) = 0.2282401$
 $Mu = MRc (4.14) = 1.6904E+008$
 $u = su (4.1) = 1.4516822E-005$

 Calculation of ratio lb/ld

 Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Shear Strength $V_r = Min(V_{r1}, V_{r2}) = 409432.244$

 Calculation of Shear Strength at edge 1, $V_{r1} = 409432.244$
 $V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 409432.244$
 $knl = 1$ (zero step-static loading)

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

 $= 1$ (normal-weight concrete)
 $fc' = 20.00$, but $fc'^{0.5} <= 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $Mu = 8.5689464E-013$
 $Vu = 8.5800179E-032$
 $d = 0.8 * h = 400.00$
 $Nu = 4716.808$
 $Ag = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 279249.888$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 100.00$$

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

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

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

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

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

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

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

$$E_f = 64828.00$$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$

$$b_w = 250.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 409432.244$

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

$$V_{CoI0} = 409432.244$$

$k_{nl} = 1$ (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).

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

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

$$M/Vd = 2.00$$

$$M_u = 8.5689464E-013$$

$$V_u = 8.5800179E-032$$

$$d = 0.8 \cdot h = 400.00$$

$$N_u = 4716.808$$

$$A_g = 125000.00$$

From (11.5.4.8), ACI 318-14: $V_s = 279249.888$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 100.00$$

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

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

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

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

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

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

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

$$E_f = 64828.00$$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$

$$b_w = 250.00$$

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

At local axis: 2

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

At local axis: 2

Integration Section: (b)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\phi = 1.00$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_b/l_d = 0.30$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $bi = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -3.6047496E-011$

Shear Force, $V_2 = 3853.513$

Shear Force, $V_3 = -3.4695601E-014$

Axial Force, $F = -4772.994$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{l,ten} = 1137.257$

-Compression: $As_{l,com} = 1137.257$

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

Mean Diameter of Tension Reinforcement, $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \phi * u = 0.00692703$

$u = \gamma + \rho = 0.00692703$

- Calculation of γ -

$\gamma = (M_y * L_s / 3) / E_{eff} = 0.00692703 ((4.29), Biskinis Phd)$

My = 5.6875E+007
Ls = M/V (with Ls > 0.1*L and Ls < 2*L) = 1500.00
From table 10.5, ASCE 41_17: Eleff = factor*Ec*Ig = 4.1053E+012
factor = 0.30
Ag = 125000.00
fc' = 20.00
N = 4772.994
Ec*Ig = 1.3684E+013

Calculation of Yielding Moment My

Calculation of ϕ_y and My according to Annex 7 -

y = Min(ϕ_{y_ten} , ϕ_{y_com})
 ϕ_{y_ten} = 9.2393283E-006
with ((10.1), ASCE 41-17) ϕ_y = Min(ϕ_y , $1.25*\phi_y*(l_b/d)^{2/3}$) = 248.9644
d = 208.00
y = 0.35225571
A = 0.02592123
B = 0.01565122
with pt = 0.01093516
pc = 0.01093516
pv = 0.00386658
N = 4772.994
b = 500.00
" = 0.20192308
 ϕ_{y_comp} = 2.3973960E-005
with $\phi_{c'}$ (12.3, (ACI 440)) = 20.44353
fc = 20.00
fl = 0.9425867
b = 500.00
h = 250.00
Ag = 125000.00
From (12.9), ACI 440: ka = 0.15009543
g = pt + pc + pv = 0.02573689
rc = 40.00
Ae/Ac = 0.60038173
Effective FRP thickness, t_f = NL*t*cos(b1) = 1.016
effective strain from (12.5) and (12.12), ϵ_{fe} = 0.004
fu = 0.01
Ef = 64828.00
Ec = 21019.039
y = 0.35108518
A = 0.02560582
B = 0.01546688
with Es = 200000.00

Calculation of ratio l_b/d

Inadequate Lap Length with l_b/d = 0.30

- Calculation of ϕ_p -

From table 10-8: ϕ_p = 0.00

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$
shear control ratio $V_y E / C_o I_{OE}$ = 0.1467291
d = 208.00
s = 0.00
 $t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$
Av = 157.0796, is the total area of all stirrups parallel to loading (shear) direction
bw = 500.00

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

$$N_{UD} = 4772.994$$

$$A_g = 125000.00$$

$$f_{cE} = 20.00$$

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

$$p_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.02573689$$

$$b = 500.00$$

$$d = 208.00$$

$$f_{cE} = 20.00$$

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

At local axis: 2

Integration Section: (b)

Calculation No. 7

column C1, Floor 1

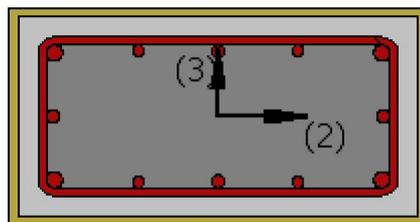
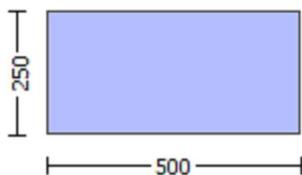
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (3)



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

At local axis: 3

Integration Section: (b)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = l_b/l_d = 0.30$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -6.8036747E-011$

Shear Force, $V_a = 3.4695601E-014$

EDGE -B-

Bending Moment, $M_b = -3.6047496E-011$

Shear Force, $V_b = -3.4695601E-014$

BOTH EDGES

Axial Force, $F = -4772.994$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression: $A_{sl,c} = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1137.257$

-Compression: $A_{sl,com} = 1137.257$

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

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 330379.134$

V_n ((10.3), ASCE 41-17) = $k_n \phi V_{Col} = 330379.134$

$V_{Col} = 330379.134$

$k_n = 1.00$

$displacement_ductility_demand = 0.00$

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

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

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

$M/Vd = 2.00$

$\mu_u = 3.6047496E-011$

$\mu_v = 3.4695601E-014$

$d = 0.8 \cdot h = 200.00$

$N_u = 4772.994$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 125663.706$

$A_v = 157079.633$

$f_y = 400.00$

$s = 100.00$

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

$s/d = 0.50$

V_f ((11-3)-(11.4), ACI 440) = 109599.773

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 208.00

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 265721.532$

$b_w = 500.00$

displacement_ductility_demand is calculated as δ / y

- Calculation of δ / y for END B -

for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 2.0196095E-022$

$y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00692703$ ((4.29), Biskinis Phd)

$M_y = 5.6875E+007$

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

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

factor = 0.30

$A_g = 125000.00$

$f_c' = 20.00$

$N = 4772.994$

$E_c \cdot I_g = 1.3684E+013$

Calculation of Yielding Moment M_y

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

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

$y_{\text{ten}} = 9.2393283E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 248.9644$

$d = 208.00$

$y = 0.35225571$

$A = 0.02592123$

$B = 0.01565122$

with $pt = 0.01093516$

$pc = 0.01093516$

$pv = 0.00386658$

$N = 4772.994$

$b = 500.00$

" = 0.20192308
y_comp = 2.3973960E-005
with f_c^* (12.3, (ACI 440)) = 20.44353
f_c = 20.00
f_l = 0.9425867
b = 500.00
h = 250.00
A_g = 125000.00
From (12.9), ACI 440: $k_a = 0.15009543$
g = p_t + p_c + p_v = 0.02573689
r_c = 40.00
A_e/A_c = 0.60038173
Effective FRP thickness, t_f = NL*t*cos(b1) = 1.016
effective strain from (12.5) and (12.12), e_f_e = 0.004
f_u = 0.01
E_f = 64828.00
E_c = 21019.039
y = 0.35108518
A = 0.02560582
B = 0.01546688
with E_s = 200000.00

Calculation of ratio l_b/l_d

Inadequate Lap Length with l_b/l_d = 0.30

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

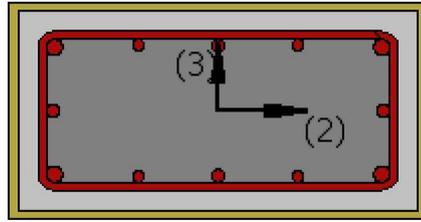
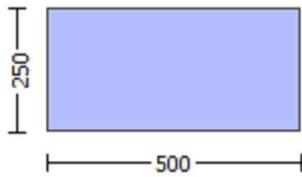
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: End

Local Axis: (3)



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

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

Constant Properties

Knowledge Factor, $\gamma = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$

 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.13916
 Element Length, $L = 3000.00$

Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
 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, $V_a = -3.6206709E-031$
 EDGE -B-
 Shear Force, $V_b = 3.6206709E-031$
 BOTH EDGES
 Axial Force, $F = -4716.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: Asl,t = 0.00

-Compression: Asl,c = 2676.637

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: Asl,ten = 1137.257

-Compression: Asl,com = 1137.257

-Middle: Asl,mid = 402.1239

Calculation of Shear Capacity ratio , $V_e/V_r = 0.1467291$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 52248.951$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 7.8373E+007$

$M_{u1+} = 7.8373E+007$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 7.8373E+007$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 7.8373E+007$

$M_{u2+} = 7.8373E+007$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 7.8373E+007$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of M_{u1+}

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

$\phi_u = 3.3776478E-005$

$M_u = 7.8373E+007$

with full section properties:

$b = 500.00$

$d = 208.00$

$d' = 42.00$

$v = 0.0022677$

$N = 4716.808$

$f_c = 20.00$

ϕ_{co} (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_{co}) = 0.01470636$

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

From (5.4b), TBDY: $\phi_u = 0.01470636$

ϕ_{ve} ((5.4c), TBDY) = $\phi_u * \text{sh}_{\min} * f_{yve}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07848902$

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

$\phi_x = 0.07705054$

$\phi_u = 0.45253333$

$b = 500.00$

$h = 250.00$

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

$b_w = 500.00$

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

$\phi_y = 0.12936483$

$\phi_u = 0.45253333$

$b = 250.00$

$h = 500.00$

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

$b_w = 250.00$

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

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \text{Cos}(\beta_1) = 1.016$

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 = 555.55
fce = 20.00

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

y1 = 0.00129669
sh1 = 0.0044814
ft1 = 373.4467
fy1 = 311.2056
su1 = 0.00512

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

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669
sh2 = 0.0044814
ft2 = 373.4467
fy2 = 311.2056
su2 = 0.00512

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

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669
shv = 0.0044814
ftv = 373.4467
fyv = 311.2056
suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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

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 $fsv = fs = 311.2056$

with $Esv = Es = 200000.00$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.17015411$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.17015411$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.06016499$$

and confined core properties:

$$b = 440.00$$

$$d = 178.00$$

$$d' = 12.00$$

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

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

c = confinement factor = 1.13916

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.22594519$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.22594519$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.07989222$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su (4.9) = 0.27122702$$

$$Mu = MRc (4.14) = 7.8373E+007$$

$$u = su (4.1) = 3.3776478E-005$$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of $Mu1$ -

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

$$u = 3.3776478E-005$$

$$Mu = 7.8373E+007$$

with full section properties:

$$b = 500.00$$

$$d = 208.00$$

$$d' = 42.00$$

$$v = 0.0022677$$

$$N = 4716.808$$

$$fc = 20.00$$

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

Final value of cu : $cu^* = shear_factor * Max(cu, cc) = 0.01470636$

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

From (5.4b), TBDY: $cu = 0.01470636$

$$we ((5.4c), TBDY) = ase * sh,min * fywe / fce + Min(fx, fy) = 0.07848902$$

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

$$fx = 0.07705054$$

$$af = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$bw = 500.00$$

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

$f_y = 0.12936483$
 $a_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$
From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$
 $b_w = 250.00$
effective stress from (A.35), $f_{f,e} = 703.4155$

 $R = 40.00$
Effective FRP thickness, $t_f = NL*t*Cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $a_{se} ((5.4d), TBDY) = 0.05494666$
 $b_o = 440.00$
 $h_o = 190.00$
 $b_{i2} = 459400.00$
 $p_{sh,min} = Min(p_{sh,x}, p_{sh,y}) = 0.00314159$

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, $n_s = 2.00$
 $b_k = 250.00$

 $s = 100.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$

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

$y_1 = 0.00129669$
 $sh_1 = 0.0044814$
 $ft_1 = 373.4467$
 $fy_1 = 311.2056$
 $su_1 = 0.00512$

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

$l_o/l_{o,min} = l_b/l_d = 0.30$

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

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

with $fs_1 = fs = 311.2056$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00129669$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4467$
 $fy_2 = 311.2056$
 $su_2 = 0.00512$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$

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

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

with $fs_2 = fs = 311.2056$

with $E_s = E_s = 200000.00$
 $y_v = 0.00129669$
 $sh_v = 0.0044814$
 $ft_v = 373.4467$
 $fy_v = 311.2056$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/ld = 0.30$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fs_v = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fs_v = fsv/1.2$, 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 $fsv = fs = 311.2056$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d)*(fs_1/fc) = 0.17015411$
 $2 = Asl_{com}/(b*d)*(fs_2/fc) = 0.17015411$
 $v = Asl_{mid}/(b*d)*(fsv/fc) = 0.06016499$
 and confined core properties:
 $b = 440.00$
 $d = 178.00$
 $d' = 12.00$
 $fcc (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl_{ten}/(b*d)*(fs_1/fc) = 0.22594519$
 $2 = Asl_{com}/(b*d)*(fs_2/fc) = 0.22594519$
 $v = Asl_{mid}/(b*d)*(fsv/fc) = 0.07989222$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.27122702$
 $Mu = MRc (4.14) = 7.8373E+007$
 $u = su (4.1) = 3.3776478E-005$

 Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Mu_{2+}

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

$u = 3.3776478E-005$
 $Mu = 7.8373E+007$

with full section properties:

$b = 500.00$
 $d = 208.00$
 $d' = 42.00$
 $v = 0.0022677$
 $N = 4716.808$
 $fc = 20.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01470636$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01470636$
 $w_e ((5.4c), TBDY) = ase * sh_{min} * fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.07848902$

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

$$fx = 0.07705054$$

$$af = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

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

$$bw = 500.00$$

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

$$fy = 0.12936483$$

$$af = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

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

$$bw = 250.00$$

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

$$R = 40.00$$

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

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

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

$$bo = 440.00$$

$$ho = 190.00$$

$$bi2 = 459400.00$$

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

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)

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

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

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

$$bk = 500.00$$

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

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

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

$$bk = 250.00$$

$$s = 100.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

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

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

$$y1 = 0.00129669$$

$$sh1 = 0.0044814$$

$$ft1 = 373.4467$$

$$fy1 = 311.2056$$

$$su1 = 0.00512$$

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

$$lo/lou,\text{min} = lb/ld = 0.30$$

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

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

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

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

$$\text{with } fs1 = fs = 311.2056$$

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

$$y2 = 0.00129669$$

$$sh2 = 0.0044814$$

$$ft2 = 373.4467$$

$$fy2 = 311.2056$$

$$su2 = 0.00512$$

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

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669

shv = 0.0044814

ftv = 373.4467

fyv = 311.2056

suv = 0.00512

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

lo/lou,min = lb/ld = 0.30

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 = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17015411

2 = Asl,com/(b*d)*(fs2/fc) = 0.17015411

v = Asl,mid/(b*d)*(fsv/fc) = 0.06016499

and confined core properties:

b = 440.00

d = 178.00

d' = 12.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = Asl,ten/(b*d)*(fs1/fc) = 0.22594519

2 = Asl,com/(b*d)*(fs2/fc) = 0.22594519

v = Asl,mid/(b*d)*(fsv/fc) = 0.07989222

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

su (4.9) = 0.27122702

Mu = MRc (4.14) = 7.8373E+007

u = su (4.1) = 3.3776478E-005

Calculation of ratio lb/ld

Inadequate Lap Length with lb/ld = 0.30

Calculation of Mu2-

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

u = 3.3776478E-005

Mu = 7.8373E+007

with full section properties:

b = 500.00

d = 208.00

d' = 42.00

v = 0.0022677

N = 4716.808

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01470636$

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

From (5.4b), TBDY: $cu = 0.01470636$

we ((5.4c), TBDY) = $ase * sh_{\min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.07848902$

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

fx = 0.07705054

af = 0.45253333

b = 500.00

h = 250.00

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

bw = 500.00

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

fy = 0.12936483

af = 0.45253333

b = 250.00

h = 500.00

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

bw = 250.00

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

R = 40.00

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

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = 0.05494666

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

No stirrups, ns = 2.00

bk = 500.00

psh,y (5.4d) = 0.00628319

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

No stirrups, ns = 2.00

bk = 250.00

s = 100.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.13916

y1 = 0.00129669

sh1 = 0.0044814

ft1 = 373.4467

fy1 = 311.2056

su1 = 0.00512

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

lo/lou,min = $lb/d = 0.30$

su1 = $0.4 * esu1_{\text{nominal}} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu1_{\text{nominal}} = 0.08,$

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 311.2056$

with $Es1 = Es = 200000.00$

$y2 = 0.00129669$

$sh2 = 0.0044814$

$ft2 = 373.4467$

$fy2 = 311.2056$

$su2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lou, min = lb/lb, min = 0.30$

$su2 = 0.4 \cdot esu2_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 311.2056$

with $Es2 = Es = 200000.00$

$yv = 0.00129669$

$shv = 0.0044814$

$ftv = 373.4467$

$fyv = 311.2056$

$suv = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lou, min = lb/ld = 0.30$

$suv = 0.4 \cdot esuv_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fsv = fs = 311.2056$

with $Esv = Es = 200000.00$

1 = $Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.17015411$

2 = $Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.17015411$

v = $Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.06016499$

and confined core properties:

$b = 440.00$

$d = 178.00$

$d' = 12.00$

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = $Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.22594519$

2 = $Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.22594519$

v = $Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.07989222$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < vs, y2$ - LHS eq.(4.5) is satisfied

su (4.9) = 0.27122702

$Mu = MRc$ (4.14) = 7.8373E+007

$u = su$ (4.1) = 3.3776478E-005

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 356091.268$

Calculation of Shear Strength at edge 1, $V_{r1} = 356091.268$

$V_{r1} = V_{Co1} \text{ ((10.3), ASCE 41-17)} = knl * V_{Co10}$

$V_{Co10} = 356091.268$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$M_u = 6.4608054E-012$

$V_u = 3.6206709E-031$

$d = 0.8 * h = 200.00$

$N_u = 4716.808$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 139624.944$

$A_v = 157079.633$

$f_y = 444.44$

$s = 100.00$

V_s is multiplied by $Col = 1.00$

$s/d = 0.50$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 109599.773$

$f = 0.95$, 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: $\alpha = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 208.00

$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$

$b_w = 500.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 356091.268$

$V_{r2} = V_{Co2} \text{ ((10.3), ASCE 41-17)} = knl * V_{Co10}$

$V_{Co10} = 356091.268$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$M_u = 6.4608054E-012$

$V_u = 3.6206709E-031$

$d = 0.8 * h = 200.00$

$N_u = 4716.808$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 139624.944$

$A_v = 157079.633$

$f_y = 444.44$

$s = 100.00$

V_s is multiplied by $Col = 1.00$

$s/d = 0.50$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 109599.773$

f = 0.95, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
 total thickness per orientation, $t_{f1} = NL * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 208.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $bw = 500.00$

 End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At local axis: 3

 Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rcrs

Constant Properties

 Knowledge Factor, $\gamma = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 * f_{sm} = 555.55$
 #####
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.13916
 Element Length, $L = 3000.00$
 Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou, \min} = 0.30$
 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, $V_a = 8.5800179E-032$

EDGE -B-

Shear Force, $V_b = -8.5800179E-032$

BOTH EDGES

Axial Force, $F = -4716.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 829.3805$

-Compression: $As_{c,com} = 829.3805$

-Middle: $As_{l,mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.27523624$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 112690.591$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.6904E+008$

$Mu_{1+} = 1.6904E+008$, 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

$Mu_{1-} = 1.6904E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.6904E+008$

$Mu_{2+} = 1.6904E+008$, 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

$Mu_{2-} = 1.6904E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.4516822E-005$

$M_u = 1.6904E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00206425$

$N = 4716.808$

$f_c = 20.00$

α_c (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_c, \phi_{cc}) = 0.01470636$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_c = 0.01470636$

where ϕ_{cc} ((5.4c), TBDY) = $\alpha_c * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07848902$

where $f = \alpha_f * \rho_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.07705054$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$

af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), pf = $2t_f/bw = 0.008128$
bw = 250.00
effective stress from (A.35), ff,e = 703.4155

R = 40.00
Effective FRP thickness, tf = $NL*t*\cos(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.05494666
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 = $A_{stir}*n_s = 78.53982$
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = $A_{stir}*n_s = 78.53982$
No stirrups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00129669
sh1 = 0.0044814
ft1 = 373.4467
fy1 = 311.2056
su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669
sh2 = 0.0044814
ft2 = 373.4467
fy2 = 311.2056
su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669
shv = 0.0044814
ftv = 373.4467
fyv = 311.2056
suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 0.30

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 = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11295746

2 = Asl,com/(b*d)*(fs2/fc) = 0.11295746

v = Asl,mid/(b*d)*(fsv/fc) = 0.13862961

and confined core properties:

b = 190.00

d = 427.00

d' = 13.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = Asl,ten/(b*d)*(fs1/fc) = 0.15907051

2 = Asl,com/(b*d)*(fs2/fc) = 0.15907051

v = Asl,mid/(b*d)*(fsv/fc) = 0.19522289

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

v < vs,y2 - LHS eq.(4.5) is satisfied

su (4.9) = 0.2282401

Mu = MRc (4.14) = 1.6904E+008

u = su (4.1) = 1.4516822E-005

Calculation of ratio lb/ld

Inadequate Lap Length with lb/ld = 0.30

Calculation of Mu1-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.4516822E-005

Mu = 1.6904E+008

with full section properties:

b = 250.00

d = 457.00

d' = 43.00

v = 0.00206425

N = 4716.808

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01470636

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01470636

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+ Min(fx, fy) = 0.07848902

where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.07705054
af = 0.45253333
b = 500.00
h = 250.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.004064
bw = 500.00
effective stress from (A.35), ff,e = 837.9178

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128
bw = 250.00
effective stress from (A.35), ff,e = 703.4155

R = 40.00
Effective FRP thickness, tf = NL*t*cos(b1) = 1.016
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 = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00129669
sh1 = 0.0044814
ft1 = 373.4467
fy1 = 311.2056
su1 = 0.00512
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 0.30
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 = 311.2056
with Es1 = Es = 200000.00
y2 = 0.00129669
sh2 = 0.0044814
ft2 = 373.4467
fy2 = 311.2056
su2 = 0.00512
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669

shv = 0.0044814

ftv = 373.4467

fyv = 311.2056

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/ld = 0.30

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 = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11295746

2 = Asl,com/(b*d)*(fs2/fc) = 0.11295746

v = Asl,mid/(b*d)*(fsv/fc) = 0.13862961

and confined core properties:

b = 190.00

d = 427.00

d' = 13.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = Asl,ten/(b*d)*(fs1/fc) = 0.15907051

2 = Asl,com/(b*d)*(fs2/fc) = 0.15907051

v = Asl,mid/(b*d)*(fsv/fc) = 0.19522289

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.2282401

Mu = MRc (4.14) = 1.6904E+008

u = su (4.1) = 1.4516822E-005

Calculation of ratio lb/ld

Inadequate Lap Length with lb/ld = 0.30

Calculation of Mu2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.4516822E-005

Mu = 1.6904E+008

with full section properties:

b = 250.00

d = 457.00

$d' = 43.00$

$v = 0.00206425$

$N = 4716.808$

$fc = 20.00$

$co (5A.5, TBDY) = 0.002$

Final value of cu : $cu^* = shear_factor * Max(cu, cc) = 0.01470636$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01470636$

we ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + Min(f_x, f_y) = 0.07848902$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07705054$

$af = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $ff_e = 837.9178$

 $f_y = 0.12936483$

$af = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff_e = 703.4155$

 $R = 40.00$

Effective FRP thickness, $tf = NL * t * Cos(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase ((5.4d), TBDY) = 0.05494666$

$bo = 440.00$

$ho = 190.00$

$bi2 = 459400.00$

$psh_{min} = Min(psh_x, psh_y) = 0.00314159$

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, $ns = 2.00$

$bk = 250.00$

 $s = 100.00$

$fy_{we} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$

$c = confinement\ factor = 1.13916$

$y1 = 0.00129669$

$sh1 = 0.0044814$

$ft1 = 373.4467$

$fy1 = 311.2056$

$su1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou_{min} = lb/d = 0.30$

$su1 = 0.4 * esu1_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered

characteristic value $f_{sy1} = f_{s1}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s1} = f_s = 311.2056$

with $E_{s1} = E_s = 200000.00$

$y_2 = 0.00129669$

$sh_2 = 0.0044814$

$ft_2 = 373.4467$

$fy_2 = 311.2056$

$su_2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$

$su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$

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 $f_{s2} = f_s = 311.2056$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.00129669$

$sh_v = 0.0044814$

$ft_v = 373.4467$

$fy_v = 311.2056$

$su_v = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30$

$su_v = 0.4 \cdot esu_{v,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu_{v,nominal} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $esu_{v,nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $f_{syv} = f_{sv}/1.2$, 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 $f_{sv} = f_s = 311.2056$

with $E_{sv} = E_s = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.11295746$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.11295746$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.13862961$

and confined core properties:

$b = 190.00$

$d = 427.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 22.78316$

$cc (5A.5, TBDY) = 0.00339158$

c = confinement factor = 1.13916

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.15907051$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.15907051$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.19522289$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.2282401$

$\mu_u = MR_c (4.14) = 1.6904E+008$

u = $su (4.1) = 1.4516822E-005$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{u2} -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.4516822E-005$$

$$\mu = 1.6904E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00206425$$

$$N = 4716.808$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_c) = 0.01470636$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.01470636$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e^* \text{ sh}_{,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s e \text{ ((5.4d), TBDY)} = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.00314159$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00628319$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00129669$$

$$sh_1 = 0.0044814$$

$$ft1 = 373.4467$$

$$fy1 = 311.2056$$

$$su1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/d = 0.30$$

$$su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 311.2056$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00129669$$

$$sh2 = 0.0044814$$

$$ft2 = 373.4467$$

$$fy2 = 311.2056$$

$$su2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.30$$

$$su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 311.2056$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00129669$$

$$shv = 0.0044814$$

$$ftv = 373.4467$$

$$fyv = 311.2056$$

$$suv = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/d = 0.30$$

$$suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 311.2056$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.11295746$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.11295746$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.13862961$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.15907051$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.15907051$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.19522289$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.2282401$$

$$Mu = MRc (4.14) = 1.6904E+008$$

$$u = su(4.1) = 1.4516822E-005$$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 409432.244$

Calculation of Shear Strength at edge 1, $V_{r1} = 409432.244$

$V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Col0}$

$$V_{Col0} = 409432.244$$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$M_u = 8.5689464E-013$$

$$V_u = 8.5800179E-032$$

$$d = 0.8 * h = 400.00$$

$$N_u = 4716.808$$

$$A_g = 125000.00$$

From (11.5.4.8), ACI 318-14: $V_s = 279249.888$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 100.00$$

V_s is multiplied by $\phi_{Col} = 1.00$

$$s/d = 0.25$$

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 $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = 45^\circ + 90^\circ = 135^\circ$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{Dir} = 1.016$

$d_{fv} = d$ (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: $V_s + V_f \leq 297085.704$

$$b_w = 250.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 409432.244$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Col0}$

$$V_{Col0} = 409432.244$$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$M_u = 8.5689464E-013$$

$$V_u = 8.5800179E-032$$

$$d = 0.8 * h = 400.00$$

Nu = 4716.808
 Ag = 125000.00
 From (11.5.4.8), ACI 318-14: Vs = 279249.888
 Av = 157079.633
 fy = 444.44
 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) $\sin^2 + \cos^2$ is replaced with $(\cot^2 + \csc^2)\sin^2\alpha$ which is more a generalised expression,
 where α is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function Vf(α), is implemented for every different fiber orientation ai,
 as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\alpha_1 = b1 + 90^\circ = 90.00$
 Vf = Min(|Vf(45, α_1)|, |Vf(-45, α_1)|), with:
 total thickness per orientation, tf1 = NL*t/NoDir = 1.016
 dfv = d (figure 11.2, ACI 440) = 457.00
 ffe ((11-5), ACI 440) = 259.312
 Ef = 64828.00
 fe = 0.004, from (11.6a), ACI 440
 with fu = 0.01
 From (11-11), ACI 440: Vs + Vf <= 297085.704
 bw = 250.00

 End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At local axis: 2

 Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
 At local axis: 3
 Integration Section: (b)
 Section Type: rcrs

Constant Properties

 Knowledge Factor, $\gamma = 1.00$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00
 Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44
 Concrete Elasticity, Ec = 21019.039
 Steel Elasticity, Es = 200000.00
 Section Height, H = 250.00
 Section Width, W = 500.00
 Cover Thickness, c = 25.00
 Element Length, L = 3000.00
 Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with lb/ld = 0.30
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, t = 1.016
 Tensile Strength, ffu = 1055.00
 Tensile Modulus, Ef = 64828.00
 Elongation, efu = 0.01
 Number of directions, NoDir = 1
 Fiber orientations, bi: 0.00°

Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

Bending Moment, M = 33515.919
Shear Force, V2 = 3853.513
Shear Force, V3 = -3.4695601E-014
Axial Force, F = -4772.994
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 2676.637
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 829.3805
-Compression: Asl,com = 829.3805
-Middle: Asl,mid = 1017.876
Mean Diameter of Tension Reinforcement, DbL = 18.66667

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u,R = * u = 0.00069587$
 $u = y + p = 0.00069587$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00069587$ ((4.29), Biskinis Phd)
 $M_y = 1.1427E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.6421E+013$
factor = 0.30
Ag = 125000.00
fc' = 20.00
N = 4772.994
 $E_c * I_g = 5.4737E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.0111358E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 248.9644$
d = 457.00
y = 0.3209156
A = 0.0235957
B = 0.01298394
with pt = 0.00725935
pc = 0.00725935
pv = 0.0089092
N = 4772.994
b = 250.00
" = 0.0940919
 $y_{comp} = 1.1987390E-005$
with fc' (12.3, (ACI 440)) = 20.44423
fc = 20.00
fl = 0.9425867
b = 250.00
h = 500.00
Ag = 125000.00
From (12.9), ACI 440: ka = 0.15033165
g = pt + pc + pv = 0.02342789
rc = 40.00

$$A_e/A_c = 0.60132659$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \cos(\beta_1) = 1.016$$

effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 21019.039$$

$$y = 0.31958736$$

$$A = 0.02330859$$

$$B = 0.01281613$$

$$\text{with } E_s = 200000.00$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

- Calculation of p -

From table 10-8: $p = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
shear control ratio $V_y E / V_{Col} I_{OE} = 0.27523624$

$$d = 457.00$$

$$s = 0.00$$

$$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$$

$A_v = 157.0796$, 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.

$$N_{UD} = 4772.994$$

$$A_g = 125000.00$$

$$f_{cE} = 20.00$$

$$f_{ytE} = f_{ylE} = 0.00$$

$$p_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.02342789$$

$$b = 250.00$$

$$d = 457.00$$

$$f_{cE} = 20.00$$

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (b)

Calculation No. 9

column C1, Floor 1

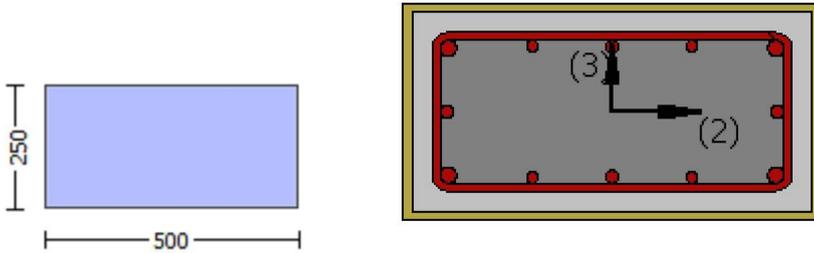
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = l_b/l_d = 0.30$

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 = -7.3539E+006
Shear Force, Va = -2443.62
EDGE -B-
Bending Moment, Mb = 21253.373
Shear Force, Vb = 2443.62
BOTH EDGES
Axial Force, F = -4752.437
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Asc = 2676.637
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 829.3805
-Compression: Asl,com = 829.3805
-Middle: Asl,mid = 1017.876
Mean Diameter of Tension Reinforcement, DbL,ten = 18.66667

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = V_n = 316017.317$
 V_n ((10.3), ASCE 41-17) = $k_n V_{CoI} = 316017.317$
 $V_{CoI} = 316017.317$
 $k_n = 1.00$
displacement_ductility_demand = 0.01776819

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)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 7.3539E+006$
 $V_u = 2443.62$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4752.437$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 251327.412$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 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 $V_f(\theta, \alpha)$, 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: $\theta = 45^\circ + 90^\circ = 135^\circ$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, \alpha_1)|)$, with:
total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 265721.532$

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 $\theta = 0.00012403$
 $y = (M_y * L_s / 3) / E_{eff} = 0.00698037$ ((4.29), Biskinis Phd)
 $M_y = 1.1427E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3009.429
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.6421E+013$
factor = 0.30
 $A_g = 125000.00$
 $f_c' = 20.00$
 $N = 4752.437$
 $E_c * I_g = 5.4737E+013$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.0110853E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / d)^{2/3}) = 248.9644$
 $d = 457.00$
 $y = 0.32090703$
 $A = 0.02359497$
 $B = 0.01298321$
with $p_t = 0.00725935$
 $p_c = 0.00725935$
 $p_v = 0.0089092$
 $N = 4752.437$
 $b = 250.00$
 $\theta = 0.0940919$
 $y_{comp} = 1.1987499E-005$
with $f_c' (12.3, (ACI 440)) = 20.44423$
 $f_c = 20.00$
 $f_l = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $A_g = 125000.00$
From (12.9), ACI 440: $k_a = 0.15033165$
 $g = p_t + p_c + p_v = 0.02342789$
 $r_c = 40.00$
 $A_e / A_c = 0.60132659$
Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.31958447$
 $A = 0.0233091$
 $B = 0.01281613$
with $E_s = 200000.00$

Calculation of ratio l_b / d

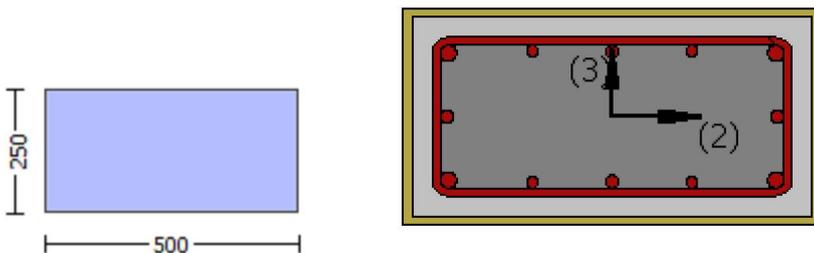
Inadequate Lap Length with $l_b / d = 0.30$

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: Life Safety (data interpolation between analysis steps 1 and 2)
Analysis: Uniform +X
Check: Chord rotation capacity (θ)
Edge: Start
Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At Shear local axis: 3
(Bending local axis: 2)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

Section Height, $H = 250.00$
Section Width, $W = 500.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.13916
Element Length, $L = 3000.00$
Secondary Member

Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
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, $V_a = -3.6206709E-031$
EDGE -B-
Shear Force, $V_b = 3.6206709E-031$
BOTH EDGES
Axial Force, $F = -4716.808$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 2676.637$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1137.257$
-Compression: $As_{l,com} = 1137.257$
-Middle: $As_{l,mid} = 402.1239$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.1467291$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 52248.951$
with
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 7.8373E+007$
 $Mu_{1+} = 7.8373E+007$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $Mu_{1-} = 7.8373E+007$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 7.8373E+007$
 $Mu_{2+} = 7.8373E+007$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the the static loading combination
 $Mu_{2-} = 7.8373E+007$, is the ultimate moment strength at the edge 2 of the member in the opposite moment
direction which is defined for the the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 3.3776478E-005$
 $M_u = 7.8373E+007$

with full section properties:
 $b = 500.00$
 $d = 208.00$
 $d' = 42.00$
 $v = 0.0022677$

N = 4716.808

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01470636$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01470636$

we ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.07848902$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.07705054

af = 0.45253333

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

bw = 500.00

effective stress from (A.35), $ff_e = 837.9178$

fy = 0.12936483

af = 0.45253333

b = 250.00

h = 500.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

bw = 250.00

effective stress from (A.35), $ff_e = 703.4155$

R = 40.00

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = 0.05494666

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 = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$

c = confinement factor = 1.13916

y1 = 0.00129669

sh1 = 0.0044814

ft1 = 373.4467

fy1 = 311.2056

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = $lb/ld = 0.30$

su1 = $0.4 * esu1_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s1} = f_s = 311.2056$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.00129669$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4467$
 $fy_2 = 311.2056$
 $su_2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.30$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 311.2056$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00129669$
 $sh_v = 0.0044814$
 $ft_v = 373.4467$
 $fy_v = 311.2056$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.30$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsy_v = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsy_v = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 311.2056$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.17015411$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.17015411$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.06016499$
 and confined core properties:
 $b = 440.00$
 $d = 178.00$
 $d' = 12.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.22594519$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.22594519$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.07989222$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_s, y_2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.27122702$
 $Mu = MRc (4.14) = 7.8373E+007$
 $u = su (4.1) = 3.3776478E-005$

 Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Mu_1 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 3.3776478E-005$$

$$M_u = 7.8373E+007$$

with full section properties:

$$b = 500.00$$

$$d = 208.00$$

$$d' = 42.00$$

$$v = 0.0022677$$

$$N = 4716.808$$

$$f_c = 20.00$$

$$\omega (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_c) = 0.01470636$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_c = 0.01470636$$

$$\omega_e (5.4c, \text{TBDY}) = \text{ase} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\text{ase ((5.4d), TBDY) = 0.05494666}$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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)

$$p_{sh,x} (5.4d) = 0.00314159$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} (5.4d) = 0.00628319$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \mu_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00129669$$

$$sh_1 = 0.0044814$$

$$f_{t1} = 373.4467$$

$$f_{y1} = 311.2056$$

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669

sh2 = 0.0044814

ft2 = 373.4467

fy2 = 311.2056

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669

shv = 0.0044814

ftv = 373.4467

fyv = 311.2056

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17015411

2 = Asl,com/(b*d)*(fs2/fc) = 0.17015411

v = Asl,mid/(b*d)*(fsv/fc) = 0.06016499

and confined core properties:

b = 440.00

d = 178.00

d' = 12.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = Asl,ten/(b*d)*(fs1/fc) = 0.22594519

2 = Asl,com/(b*d)*(fs2/fc) = 0.22594519

v = Asl,mid/(b*d)*(fsv/fc) = 0.07989222

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

v < vs,y2 - LHS eq.(4.5) is satisfied

su (4.9) = 0.27122702

Mu = MRc (4.14) = 7.8373E+007

u = su (4.1) = 3.3776478E-005

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 3.3776478E-005$

$\mu_{2+} = 7.8373E+007$

with full section properties:

$b = 500.00$

$d = 208.00$

$d' = 42.00$

$v = 0.0022677$

$N = 4716.808$

$f_c = 20.00$

ω (5A.5, TBDY) = 0.002

Final value of μ_c : $\mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01470636$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.01470636$

ω_e ((5.4c), TBDY) = $\text{ase} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$

where $f = \text{af} * \text{pf} * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.07705054$

$\text{af} = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f/b_w = 0.004064$

$b_w = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$

$\text{af} = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = N L^* t \text{Cos}(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

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

$A_{sh} = A_{\text{stir}} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 250.00$

$s = 100.00$
 $fy_{we} = 555.55$
 $f_{ce} = 20.00$
 From ((5.A.5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $y_1 = 0.00129669$
 $sh_1 = 0.0044814$
 $ft_1 = 373.4467$
 $fy_1 = 311.2056$
 $su_1 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/d = 0.30$
 $su_1 = 0.4 * esu_1 \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esu_1 \text{ nominal} = 0.08$,
 For calculation of $esu_1 \text{ nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 311.2056$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.00129669$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4467$
 $fy_2 = 311.2056$
 $su_2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/lb, \min = 0.30$
 $su_2 = 0.4 * esu_2 \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esu_2 \text{ nominal} = 0.08$,
 For calculation of $esu_2 \text{ nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 311.2056$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.00129669$
 $sh_v = 0.0044814$
 $ft_v = 373.4467$
 $fy_v = 311.2056$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/d = 0.30$
 $suv = 0.4 * esuv \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esuv \text{ nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv \text{ nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 311.2056$
 with $Esv = Es = 200000.00$
 $1 = Asl, \text{ten}/(b * d) * (fs_1/fc) = 0.17015411$
 $2 = Asl, \text{com}/(b * d) * (fs_2/fc) = 0.17015411$
 $v = Asl, \text{mid}/(b * d) * (fsv/fc) = 0.06016499$
 and confined core properties:
 $b = 440.00$
 $d = 178.00$
 $d' = 12.00$
 $f_{cc} \text{ (5A.2, TBDY)} = 22.78316$
 $cc \text{ (5A.5, TBDY)} = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl, \text{ten}/(b * d) * (fs_1/fc) = 0.22594519$
 $2 = Asl, \text{com}/(b * d) * (fs_2/fc) = 0.22594519$

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.07989222$$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u(4.9) = 0.27122702$$

$$M_u = M_{Rc}(4.14) = 7.8373E+007$$

$$u = s_u(4.1) = 3.3776478E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u2} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 3.3776478E-005$$

$$M_u = 7.8373E+007$$

with full section properties:

$$b = 500.00$$

$$d = 208.00$$

$$d' = 42.00$$

$$v = 0.0022677$$

$$N = 4716.808$$

$$f_c = 20.00$$

$$\alpha(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \alpha: \alpha^* = \text{shear_factor} \cdot \text{Max}(\alpha, \alpha_c) = 0.01470636$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \alpha_c = 0.01470636$$

$$\alpha_{we}((5.4c), TBDY) = \alpha_{se} \cdot \text{sh}_{, \min} \cdot f_{ywe} / f_{ce} + \text{Min}(\alpha_x, \alpha_y) = 0.07848902$$

where $\alpha_f = \alpha_f \cdot p_f \cdot f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\alpha_x = 0.07705054$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$\alpha_y = 0.12936483$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(\beta_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se}((5.4d), TBDY) = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh, \min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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 = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00129669
sh1 = 0.0044814

ft1 = 373.4467
fy1 = 311.2056

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669

sh2 = 0.0044814

ft2 = 373.4467

fy2 = 311.2056

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669

shv = 0.0044814

ftv = 373.4467

fyv = 311.2056

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17015411

2 = Asl,com/(b*d)*(fs2/fc) = 0.17015411

$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.06016499$
 and confined core properties:
 $b = 440.00$
 $d = 178.00$
 $d' = 12.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22594519$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.22594519$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07989222$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.27122702$
 $Mu = MRc (4.14) = 7.8373E+007$
 $u = su (4.1) = 3.3776478E-005$

 Calculation of ratio l_b/l_d

 Inadequate Lap Length with $l_b/l_d = 0.30$

 Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 356091.268$

 Calculation of Shear Strength at edge 1, $V_{r1} = 356091.268$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$
 $V_{Col0} = 356091.268$
 $k_{nl} = 1$ (zero step-static loading)

 NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_{s+} = f * V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $Mu = 6.4608054E-012$
 $Vu = 3.6206709E-031$
 $d = 0.8 * h = 200.00$
 $Nu = 4716.808$
 $Ag = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 139624.944$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 100.00$
 V_s is multiplied by $Col = 1.00$
 $s/d = 0.50$
 $V_f ((11-3)-(11.4), ACI 440) = 109599.773$
 $f = 0.95$, 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) = 208.00
 $f_{fe} ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $bw = 500.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 356091.268$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 356091.268$
 $knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$
 $\mu_u = 6.4608054E-012$
 $V_u = 3.6206709E-031$

$d = 0.8 * h = 200.00$
 $N_u = 4716.808$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 139624.944$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 100.00$

V_s is multiplied by $Col = 1.00$
 $s/d = 0.50$

$V_f ((11-3)-(11.4), ACI 440) = 109599.773$
 $f = 0.95$, 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 $V_f(a, \theta)$, 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: $\theta_1 = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 208.00

$f_{fe} ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $bw = 500.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$

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, $V_a = 8.5800179E-032$

EDGE -B-

Shear Force, $V_b = -8.5800179E-032$

BOTH EDGES

Axial Force, $F = -4716.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 829.3805$

-Compression: $As_{l,com} = 829.3805$

-Middle: $As_{l,mid} = 1017.876$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.27523624$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 112690.591$

with

$M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 1.6904E+008$

$\mu_{u1+} = 1.6904E+008$, 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

$\mu_{u1-} = 1.6904E+008$, 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

$M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 1.6904E+008$

$\mu_{u2+} = 1.6904E+008$, 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

$\mu_{u2-} = 1.6904E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of μ_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.4516822E-005$$

$$\mu = 1.6904E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00206425$$

$$N = 4716.808$$

$$f_c = 20.00$$

$$\alpha (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01470636$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01470636$$

$$\omega_e \text{ ((5.4c), TBDY) } = \alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07848902$$

where $\phi = \alpha * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.07705054$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$\phi_y = 0.12936483$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(\beta_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$\alpha s_e \text{ ((5.4d), TBDY) } = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$\text{psh}_{\min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.00314159$$

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)

$$\text{psh}_x \text{ (5.4d) } = 0.00314159$$

$$A_{sh} = A_{\text{stir}} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$\text{psh}_y \text{ (5.4d) } = 0.00628319$$

$$A_{sh} = A_{\text{stir}} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00129669$$

$$sh_1 = 0.0044814$$

$$ft_1 = 373.4467$$

$$fy_1 = 311.2056$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.30$$

$$s_u1 = 0.4 * e_{su1,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su1,nominal} = 0.08$,

For calculation of $e_{su1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $f_{sy1} = f_s/1.2$, 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.

$$\text{with } f_{s1} = f_s = 311.2056$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.00129669$$

$$sh_2 = 0.0044814$$

$$ft_2 = 373.4467$$

$$fy_2 = 311.2056$$

$$s_u2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$$

$$s_u2 = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su2,nominal} = 0.08$,

For calculation of $e_{su2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $f_{sy2} = f_s/1.2$, 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.

$$\text{with } f_{s2} = f_s = 311.2056$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.00129669$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4467$$

$$fy_v = 311.2056$$

$$s_{uv} = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.30$$

$$s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY
For calculation of $e_{suv,nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $f_{sv} = f_s/1.2$, 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.

$$\text{with } f_{sv} = f_s = 311.2056$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.11295746$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.11295746$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.13862961$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.15907051$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.15907051$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.19522289$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

---->

$$s_u (4.9) = 0.2282401$$

$$\mu_u = M_{Rc} (4.14) = 1.6904E+008$$

$$u = s_u (4.1) = 1.4516822E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_1

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.4516822E-005$$

$$\mu_1 = 1.6904E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00206425$$

$$N = 4716.808$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01470636$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01470636$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(\beta_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.00314159$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00628319$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 100.00$$

$$fy_{we} = 555.55$$

$$f_{ce} = 20.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00339158$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00129669$$

$$sh_1 = 0.0044814$$

$$ft_1 = 373.4467$$

$$fy_1 = 311.2056$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/ld = 0.30$$

$$su_1 = 0.4 * esu_{1_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{1_nominal} = 0.08$,

For calculation of $esu_{1_nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 311.2056$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00129669$$

$$sh_2 = 0.0044814$$

$$ft_2 = 373.4467$$

$$fy_2 = 311.2056$$

$$su_2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/lb, \min = 0.30$$

$$su_2 = 0.4 * esu_{2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{2_nominal} = 0.08$,

For calculation of $esu_{2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 311.2056$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00129669$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4467$$

$$fy_v = 311.2056$$

$$su_v = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/ld = 0.30$$

$$su_v = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_nominal$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 311.2056$$

$$\text{with } Es_v = Es = 200000.00$$

$$1 = Asl, \text{ten}/(b*d) * (fs_1/fc) = 0.11295746$$

$$2 = Asl, \text{com}/(b*d) * (fs_2/fc) = 0.11295746$$

$$v = Asl, \text{mid}/(b*d) * (fsv/fc) = 0.13862961$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = Asl, \text{ten}/(b*d) * (fs_1/fc) = 0.15907051$$

$$2 = Asl, \text{com}/(b*d) * (fs_2/fc) = 0.15907051$$

$$v = Asl, \text{mid}/(b*d) * (fsv/fc) = 0.19522289$$

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) = 0.2282401
 $M_u = M_{Rc}$ (4.14) = 1.6904E+008
 $u = s_u$ (4.1) = 1.4516822E-005

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 1.4516822E-005$
 $M_u = 1.6904E+008$

with full section properties:

$b = 250.00$
 $d = 457.00$
 $d' = 43.00$
 $v = 0.00206425$
 $N = 4716.808$
 $f_c = 20.00$
 α (5A.5, TBDY) = 0.002

Final value of α : $\alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01470636$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\alpha_c = 0.01470636$

α_{we} ((5.4c), TBDY) = $\alpha_{se} * \text{sh_min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$

where $f = \alpha * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07705054$
 $\alpha_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.004064$
 $bw = 500.00$
effective stress from (A.35), $f_{fe} = 837.9178$

 $f_y = 0.12936483$
 $\alpha_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.008128$
 $bw = 250.00$
effective stress from (A.35), $f_{fe} = 703.4155$

 $R = 40.00$
Effective FRP thickness, $t_f = NL * t * \text{Cos}(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{f} = 0.015$
 α_{se} ((5.4d), TBDY) = 0.05494666
 $b_o = 440.00$
 $h_o = 190.00$
 $b_{i2} = 459400.00$

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$

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 = 555.55
fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00129669
sh1 = 0.0044814
ft1 = 373.4467
fy1 = 311.2056
su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669
sh2 = 0.0044814
ft2 = 373.4467
fy2 = 311.2056
su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669
shv = 0.0044814
ftv = 373.4467
fyv = 311.2056
suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 0.30

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 = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11295746

2 = Asl,com/(b*d)*(fs2/fc) = 0.11295746

v = Asl,mid/(b*d)*(fsv/fc) = 0.13862961

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.15907051$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.15907051$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.19522289$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.2282401$$

$$\mu_u = M_{Rc} (4.14) = 1.6904E+008$$

$$u = s_u (4.1) = 1.4516822E-005$$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_{u2} -

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.4516822E-005$$

$$\mu_u = 1.6904E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00206425$$

$$N = 4716.808$$

$$f_c = 20.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01470636$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01470636$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$a_s e ((5.4d), \text{TBDY}) = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh, \min} = \text{Min}(p_{sh, x}, p_{sh, y}) = 0.00314159$$

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)

$$p_{sh, x} (5.4d) = 0.00314159$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh, y} (5.4d) = 0.00628319$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From } ((5.A.5), \text{TBDY}), \text{TBDY: } c_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00129669$$

$$sh_1 = 0.0044814$$

$$f_{t1} = 373.4467$$

$$f_{y1} = 311.2056$$

$$s_{u1} = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o, \min} = l_b/l_d = 0.30$$

$$s_{u1} = 0.4 * e_{s1_nominal} ((5.5), \text{TBDY}) = 0.032$$

From table 5A.1, TBDY: $e_{s1_nominal} = 0.08$,

For calculation of $e_{s1_nominal}$ and $y_1, sh_1, f_{t1}, f_{y1}$, it is considered characteristic value $f_{sy1} = f_s/1.2$, 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.

$$\text{with } f_{s1} = f_s = 311.2056$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.00129669$$

$$sh_2 = 0.0044814$$

$$f_{t2} = 373.4467$$

$$f_{y2} = 311.2056$$

$$s_{u2} = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o, \min} = l_b/l_{b, \min} = 0.30$$

$$s_{u2} = 0.4 * e_{s2_nominal} ((5.5), \text{TBDY}) = 0.032$$

From table 5A.1, TBDY: $e_{s2_nominal} = 0.08$,

For calculation of $e_{s2_nominal}$ and $y_2, sh_2, f_{t2}, f_{y2}$, it is considered characteristic value $f_{sy2} = f_s/1.2$, from table 5.1, TBDY.

$y_2, sh_2, f_{t2}, f_{y2}$, are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s2} = f_s = 311.2056$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.00129669$$

$$sh_v = 0.0044814$$

$$f_{tv} = 373.4467$$

$$f_{yv} = 311.2056$$

$$s_{uv} = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o, \min} = l_b/l_d = 0.30$$

$$s_{uv} = 0.4 * e_{suv_nominal} ((5.5), \text{TBDY}) = 0.032$$

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 $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 311.2056$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.11295746$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.11295746$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.13862961$

and confined core properties:

$b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 f_{cc} (5A.2, TBDY) = 22.78316
 cc (5A.5, TBDY) = 0.00339158
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.15907051$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.15907051$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.19522289$

Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->
 μ_u (4.9) = 0.2282401
 $\mu_u = M/R_c$ (4.14) = 1.6904E+008
 $u = \mu_u$ (4.1) = 1.4516822E-005

 Calculation of ratio l_b/l_d

 Inadequate Lap Length with $l_b/l_d = 0.30$

 Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 409432.244$

 Calculation of Shear Strength at edge 1, $V_{r1} = 409432.244$
 $V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 409432.244$
 $k_{nl} = 1$ (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).

 $f = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 8.5689464E-013$
 $V_u = 8.5800179E-032$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4716.808$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 279249.888$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 100.00$
 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 $(\cot + \csc) \sin \alpha$ 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, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:
total thickness per orientation, $t_{f1} = NL * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 409432.244$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Col0}$
 $V_{Col0} = 409432.244$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M / V d = 2.00$
 $\mu_u = 8.5689464E-013$
 $\nu_u = 8.5800179E-032$
 $d = 0.8 * h = 400.00$
 $N_u = 4716.808$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 279249.888$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 100.00$
 V_s is multiplied by $\lambda_{Col} = 1.00$
 $s / d = 0.25$

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 $(\cot \theta + \csc \theta) \sin \theta$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \theta_1)$, is implemented for every different fiber orientation θ_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:
total thickness per orientation, $t_{f1} = NL * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $b_w = 250.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
At local axis: 2
Integration Section: (a)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\phi = 1.00$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_b/l_d = 0.30$
 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, $M = -4.0780157E-011$
 Shear Force, $V_2 = -2443.62$
 Shear Force, $V_3 = 2.2001442E-014$
 Axial Force, $F = -4752.437$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{sl,t} = 0.00$
 -Compression: $A_{sl,c} = 2676.637$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{sl,ten} = 1137.257$
 -Compression: $A_{sl,com} = 1137.257$
 -Middle: $A_{sl,mid} = 402.1239$
 Mean Diameter of Tension Reinforcement, $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \phi \cdot u = 0.03692682$
 $u = y + p = 0.03692682$

- Calculation of y -

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00692682$ ((4.29), Biskinis Phd))
 $M_y = 5.6873E+007$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 4.1053E+012$
 factor = 0.30
 $A_g = 125000.00$
 $f_c' = 20.00$
 $N = 4752.437$
 $E_c \cdot I_g = 1.3684E+013$

Calculation of Yielding Moment M_y

Calculation of ρ_y and M_y according to Annex 7 -

$$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$$

$$y_{\text{ten}} = 9.2392118\text{E-}006$$

$$\text{with } ((10.1), \text{ASCE 41-17}) f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 248.9644$$

$$d = 208.00$$

$$y = 0.35224754$$

$$A = 0.02592044$$

$$B = 0.01565043$$

$$\text{with } p_t = 0.01093516$$

$$p_c = 0.01093516$$

$$p_v = 0.00386658$$

$$N = 4752.437$$

$$b = 500.00$$

$$n = 0.20192308$$

$$y_{\text{comp}} = 2.3974177\text{E-}005$$

$$\text{with } f_c^* (12.3, \text{ACI 440}) = 20.44353$$

$$f_c = 20.00$$

$$f_l = 0.9425867$$

$$b = 500.00$$

$$h = 250.00$$

$$A_g = 125000.00$$

$$\text{From } (12.9), \text{ACI 440: } k_a = 0.15009543$$

$$g = p_t + p_c + p_v = 0.02573689$$

$$r_c = 40.00$$

$$A_e/A_c = 0.60038173$$

$$\text{Effective FRP thickness, } t_f = N \cdot l \cdot \cos(b_1) = 1.016$$

$$\text{effective strain from } (12.5) \text{ and } (12.12), e_{fe} = 0.004$$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 21019.039$$

$$y = 0.35108201$$

$$A = 0.02560639$$

$$B = 0.01546688$$

$$\text{with } E_s = 200000.00$$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

- Calculation of ρ_p -

From table 10-8: $\rho_p = 0.03$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$

$$\text{shear control ratio } V_y E / V_{CoI} E = 0.1467291$$

$$d = 208.00$$

$$s = 0.00$$

$$t = A_v / (b_w \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00$$

$A_v = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$$b_w = 500.00$$

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ is implemented to account for FRP contribution

where $f = 2 \cdot t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

$$N_{UD} = 4752.437$$

$$A_g = 125000.00$$

$$f_c E = 20.00$$

$$f_{yt} E = f_{yl} E = 0.00$$

$$\rho_l = \text{Area}_{\text{Tot_Long_Rein}} / (b \cdot d) = 0.02573689$$

$$b = 500.00$$

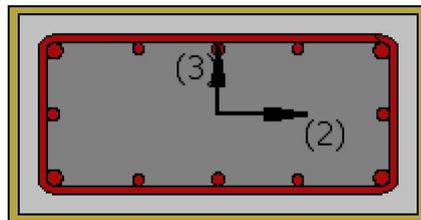
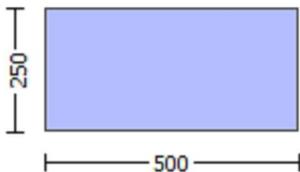
$$d = 208.00$$

$$f_c E = 20.00$$

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
At local axis: 2
Integration Section: (a)

Calculation No. 11

column C1, Floor 1
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)
Analysis: Uniform +X
Check: Shear capacity VRd
Edge: Start
Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1
At local axis: 3
Integration Section: (a)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of γ for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE41-17).
Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

Section Height, H = 250.00
Section Width, W = 500.00
Cover Thickness, c = 25.00
Element Length, L = 3000.00
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_o/l_{o,min} = l_b/l_d = 0.30$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $ε_{fu} = 0.01$
Number of directions, NoDir = 1
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -4.0780157E-011$
Shear Force, $V_a = 2.2001442E-014$
EDGE -B-
Bending Moment, $M_b = -2.5222546E-011$
Shear Force, $V_b = -2.2001442E-014$
BOTH EDGES
Axial Force, F = -4752.437
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 2676.637$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1137.257$
-Compression: $As_{c,com} = 1137.257$
-Middle: $As_{c,mid} = 402.1239$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $VR = *V_n = 330375.062$
 $V_n ((10.3), ASCE 41-17) = knl * V_{CoI} = 330375.062$
 $V_{CoI} = 330375.062$
 $knl = 1.00$
 $displacement_ductility_demand = 0.00$

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 $f'_c = 16.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 4.0780157E-011$
 $V_u = 2.2001442E-014$
 $d = 0.8 * h = 200.00$
 $N_u = 4752.437$
 $Ag = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 125663.706$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$

Vs is multiplied by Col = 1.00

s/d = 0.50

Vf ((11-3)-(11.4), ACI 440) = 109599.773

f = 0.95, for fully-wrapped sections

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(θ , α), is implemented for every different fiber orientation ai, as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

Vf = Min(|Vf(45, θ)|, |Vf(-45, θ)|), with:

total thickness per orientation, tf1 = NL*t/NoDir = 1.016

dfv = d (figure 11.2, ACI 440) = 208.00

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 <= 265721.532

bw = 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 $\theta = 1.0536655E-022$

y = (My*Ls/3)/Eleff = 0.00692682 ((4.29), Biskinis Phd)

My = 5.6873E+007

Ls = M/V (with Ls > 0.1*L and Ls < 2*L) = 1500.00

From table 10.5, ASCE 41_17: Eleff = factor*Ec*Ig = 4.1053E+012

factor = 0.30

Ag = 125000.00

fc' = 20.00

N = 4752.437

Ec*Ig = 1.3684E+013

Calculation of Yielding Moment My

Calculation of δ / y and My according to Annex 7 -

y = Min(y_ten, y_com)

y_ten = 9.2392118E-006

with ((10.1), ASCE 41-17) fy = Min(fy, 1.25*fy*(lb/d)^ 2/3) = 248.9644

d = 208.00

y = 0.35224754

A = 0.02592044

B = 0.01565043

with pt = 0.01093516

pc = 0.01093516

pv = 0.00386658

N = 4752.437

b = 500.00

" = 0.20192308

y_comp = 2.3974177E-005

with fc' (12.3, (ACI 440)) = 20.44353

fc = 20.00

fl = 0.9425867

b = 500.00

h = 250.00

Ag = 125000.00

From (12.9), ACI 440: ka = 0.15009543

g = pt + pc + pv = 0.02573689

rc = 40.00

$$A_e/A_c = 0.60038173$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b1) = 1.016$$

effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 21019.039$$

$$y = 0.35108201$$

$$A = 0.02560639$$

$$B = 0.01546688$$

with $E_s = 200000.00$

Calculation of ratio I_b/I_d

Inadequate Lap Length with $I_b/I_d = 0.30$

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

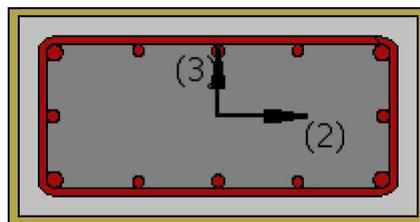
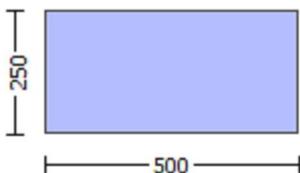
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcrs

Constant Properties

```

Knowledge Factor,  $\phi = 1.00$ 
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$ 
Existing material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 444.44$ 
Concrete Elasticity,  $E_c = 21019.039$ 
Steel Elasticity,  $E_s = 200000.00$ 
#####
Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$ 
#####
Section Height,  $H = 250.00$ 
Section Width,  $W = 500.00$ 
Cover Thickness,  $c = 25.00$ 
Mean Confinement Factor overall section = 1.13916
Element Length,  $L = 3000.00$ 
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with  $l_o/l_{ou,min} = 0.30$ 
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,  $V_a = -3.6206709E-031$ 
EDGE -B-
Shear Force,  $V_b = 3.6206709E-031$ 
BOTH EDGES
Axial Force,  $F = -4716.808$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $A_{sl,t} = 0.00$ 
-Compression:  $A_{sl,c} = 2676.637$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension:  $A_{sl,ten} = 1137.257$ 
-Compression:  $A_{sl,com} = 1137.257$ 
-Middle:  $A_{sl,mid} = 402.1239$ 
-----
-----

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.1467291$ 
Member Controlled by Flexure ( $V_e/V_r < 1$ )
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 52248.951$ 
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 7.8373E+007$ 
 $M_{u1+} = 7.8373E+007$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $M_{u1-} = 7.8373E+007$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 7.8373E+007$ 
 $M_{u2+} = 7.8373E+007$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction

```

which is defined for the the static loading combination

$\mu_{2-} = 7.8373E+007$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of μ_{1+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 3.3776478E-005$$

$$\mu_{u} = 7.8373E+007$$

with full section properties:

$$b = 500.00$$

$$d = 208.00$$

$$d' = 42.00$$

$$v = 0.0022677$$

$$N = 4716.808$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.01470636$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.01470636$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07705054$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 837.9178$$

 $f_y = 0.12936483$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

 $R = 40.00$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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)

 $p_{sh,x} \text{ (5.4d)} = 0.00314159$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

 $p_{sh,y} \text{ (5.4d)} = 0.00628319$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

 $s = 100.00$

$$fywe = 555.55$$

$$fce = 20.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00339158$

$$c = \text{confinement factor} = 1.13916$$

$$y1 = 0.00129669$$

$$sh1 = 0.0044814$$

$$ft1 = 373.4467$$

$$fy1 = 311.2056$$

$$su1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.30$$

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs1 = fs = 311.2056$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00129669$$

$$sh2 = 0.0044814$$

$$ft2 = 373.4467$$

$$fy2 = 311.2056$$

$$su2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.30$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs2 = fs = 311.2056$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00129669$$

$$shv = 0.0044814$$

$$ftv = 373.4467$$

$$fyv = 311.2056$$

$$suv = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.30$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fsv = fs = 311.2056$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.17015411$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.17015411$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.06016499$$

and confined core properties:

$$b = 440.00$$

$$d = 178.00$$

$$d' = 12.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.22594519$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.22594519$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.07989222$$

Case/Assumption: Unconfinedsd full section - Steel rupture

satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

s_u (4.9) = 0.27122702

$M_u = M_{Rc}$ (4.14) = 7.8373E+007

$u = s_u$ (4.1) = 3.3776478E-005

Calculation of ratio I_b/I_d

Inadequate Lap Length with $I_b/I_d = 0.30$

Calculation of M_{u1} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 3.3776478E-005$

$M_u = 7.8373E+007$

with full section properties:

$b = 500.00$

$d = 208.00$

$d' = 42.00$

$v = 0.0022677$

$N = 4716.808$

$f_c = 20.00$

α (5A.5, TBDY) = 0.002

Final value of α : $\alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01470636$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\alpha = 0.01470636$

ω ((5.4c), TBDY) = $\alpha * \text{sh_min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$

where $f = \alpha * \rho_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07705054$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$

$\alpha_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

α_{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

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 = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00129669
sh1 = 0.0044814
ft1 = 373.4467
fy1 = 311.2056
su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669
sh2 = 0.0044814
ft2 = 373.4467
fy2 = 311.2056
su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669
shv = 0.0044814
ftv = 373.4467
fyv = 311.2056
suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17015411

2 = Asl,com/(b*d)*(fs2/fc) = 0.17015411

v = Asl,mid/(b*d)*(fsv/fc) = 0.06016499

and confined core properties:

$b = 440.00$
 $d = 178.00$
 $d' = 12.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22594519$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.22594519$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07989222$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.27122702$
 $Mu = MRc (4.14) = 7.8373E+007$
 $u = su (4.1) = 3.3776478E-005$

 Calculation of ratio l_b/l_d

 Inadequate Lap Length with $l_b/l_d = 0.30$

 Calculation of Mu_{2+}

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 3.3776478E-005$
 $Mu = 7.8373E+007$

 with full section properties:

$b = 500.00$
 $d = 208.00$
 $d' = 42.00$
 $v = 0.0022677$
 $N = 4716.808$
 $f_c = 20.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01470636$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01470636$
 $w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$
 where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07705054$
 $a_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$
 From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.004064$
 $bw = 500.00$
 effective stress from (A.35), $f_{f,e} = 837.9178$

 $f_y = 0.12936483$
 $a_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$
 From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.008128$
 $bw = 250.00$
 effective stress from (A.35), $f_{f,e} = 703.4155$

 $R = 40.00$
 Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$

u,f = 0.015

ase ((5.4d), TBDY) = 0.05494666

bo = 440.00

ho = 190.00

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 = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158

c = confinement factor = 1.13916

y1 = 0.00129669

sh1 = 0.0044814

ft1 = 373.4467

fy1 = 311.2056

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669

sh2 = 0.0044814

ft2 = 373.4467

fy2 = 311.2056

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669

shv = 0.0044814

ftv = 373.4467

fyv = 311.2056

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY
For calculation of $e_{sv_nominal}$ and y_v , sh_v , ft_v , fy_v , it is considered characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 311.2056$

with $E_{sv} = E_s = 200000.00$

1 = $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.17015411$

2 = $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.17015411$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.06016499$

and confined core properties:

$b = 440.00$

$d = 178.00$

$d' = 12.00$

f_{cc} (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.22594519$

2 = $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.22594519$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.07989222$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.27122702

$Mu = MR_c$ (4.14) = 7.8373E+007

$u = su$ (4.1) = 3.3776478E-005

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Mu_2 -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 3.3776478E-005$

$Mu = 7.8373E+007$

with full section properties:

$b = 500.00$

$d = 208.00$

$d' = 42.00$

$v = 0.0022677$

$N = 4716.808$

$f_c = 20.00$

co (5A.5, TBDY) = 0.002

Final value of cu : $cu^* = \text{shear_factor} \cdot \text{Max}(cu, cc) = 0.01470636$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01470636$

w_e ((5.4c), TBDY) = $ase \cdot sh_{,min} \cdot fy_{we}/f_{ce} + \text{Min}(f_x, fy) = 0.07848902$

where $f = af \cdot pf \cdot f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07705054$

$af = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $pf = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{f,e} = 837.9178$

$fy = 0.12936483$

$af = 0.45253333$

b = 250.00
h = 500.00
From EC8 A 4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

R = 40.00
Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase \text{ ((5.4d), TBDY)} = 0.05494666$
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
 $fy_{we} = 555.55$
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

$y1 = 0.00129669$
 $sh1 = 0.0044814$
 $ft1 = 373.4467$
 $fy1 = 311.2056$
 $su1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou_{,min} = lb/ld = 0.30$

$su1 = 0.4*esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 311.2056$

with $Es1 = Es = 200000.00$

$y2 = 0.00129669$
 $sh2 = 0.0044814$
 $ft2 = 373.4467$
 $fy2 = 311.2056$
 $su2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou_{,min} = lb/lb_{,min} = 0.30$

$su2 = 0.4*esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and $y2, sh2, ft2, fy2$, it is considered
characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y2, sh2, ft2, fy2$, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 311.2056$

with $Es2 = Es = 200000.00$

$yv = 0.00129669$

$shv = 0.0044814$
 $ftv = 373.4467$
 $fyv = 311.2056$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 0.30$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 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 $fsv = fs = 311.2056$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.17015411$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.17015411$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.06016499$
 and confined core properties:
 $b = 440.00$
 $d = 178.00$
 $d' = 12.00$
 $fcc (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.22594519$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.22594519$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.07989222$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs,y2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.27122702$
 $Mu = MRc (4.14) = 7.8373E+007$
 $u = su (4.1) = 3.3776478E-005$

 Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Shear Strength $Vr = Min(Vr1,Vr2) = 356091.268$

Calculation of Shear Strength at edge 1, $Vr1 = 356091.268$

$Vr1 = VCol ((10.3), ASCE 41-17) = knl * VColO$

$VColO = 356091.268$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $Vs = Av*fy*d/s$ ' is replaced by ' $Vs + f*Vf$ '
 where Vf is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

$fc' = 20.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$Mu = 6.4608054E-012$

$Vu = 3.6206709E-031$

$d = 0.8*h = 200.00$

$Nu = 4716.808$

$Ag = 125000.00$

From (11.5.4.8), ACI 318-14: $Vs = 139624.944$

$Av = 157079.633$

$fy = 444.44$

$s = 100.00$
 V_s is multiplied by $Col = 1.00$
 $s/d = 0.50$
 V_f ((11-3)-(11.4), ACI 440) = 109599.773
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(\theta, a)$, 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, $tf1 = NL * t / NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 208.00
 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: $V_s + V_f \leq 297085.704$
 $bw = 500.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 356091.268$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $knl * V_{ColO}$
 $V_{ColO} = 356091.268$
 $knl = 1$ (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).

 $\rho = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 6.4608054E-012$
 $V_u = 3.6206709E-031$
 $d = 0.8 * h = 200.00$
 $N_u = 4716.808$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 139624.944$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 100.00$
 V_s is multiplied by $Col = 1.00$
 $s/d = 0.50$
 V_f ((11-3)-(11.4), ACI 440) = 109599.773
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(\theta, a)$, 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, $tf1 = NL * t / NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 208.00
 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: $V_s + V_f \leq 297085.704$
 $bw = 500.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\phi = 1.00$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, $f_s = 1.25 * f_{sm} = 555.55$

Section Height, $H = 250.00$
Section Width, $W = 500.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.13916
Element Length, $L = 3000.00$
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_o/l_{o,min} = 0.30$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $ef_u = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 8.5800179E-032$
EDGE -B-
Shear Force, $V_b = -8.5800179E-032$
BOTH EDGES
Axial Force, $F = -4716.808$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 2676.637$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{l,ten} = 829.3805$
-Compression: $As_{l,com} = 829.3805$
-Middle: $As_{l,mid} = 1017.876$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.27523624$
Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 112690.591$

with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.6904E+008$
 $M_{u1+} = 1.6904E+008$, 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
 $M_{u1-} = 1.6904E+008$, 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
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.6904E+008$
 $M_{u2+} = 1.6904E+008$, 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
 $M_{u2-} = 1.6904E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of M_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.4516822E-005$
 $M_u = 1.6904E+008$

with full section properties:

$b = 250.00$
 $d = 457.00$
 $d' = 43.00$
 $v = 0.00206425$
 $N = 4716.808$
 $f_c = 20.00$
 α_1 (5A.5, TBDY) = 0.002
Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01470636$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_u = 0.01470636$
 ω_e ((5.4c), TBDY) = $\alpha_1 * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$
where $f = \alpha_1 * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07705054$
 $\alpha_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$
From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.004064$
 $bw = 500.00$
effective stress from (A.35), $f_{fe} = 837.9178$

 $f_y = 0.12936483$
 $\alpha_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$
From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.008128$
 $bw = 250.00$
effective stress from (A.35), $f_{fe} = 703.4155$

 $R = 40.00$
Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{f} = 0.015$
 α_{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, 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 = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00129669
sh1 = 0.0044814
ft1 = 373.4467
fy1 = 311.2056
su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669
sh2 = 0.0044814
ft2 = 373.4467
fy2 = 311.2056
su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669
shv = 0.0044814
ftv = 373.4467
fyv = 311.2056
suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11295746

2 = Asl,com/(b*d)*(fs2/fc) = 0.11295746

v = Asl,mid/(b*d)*(fsv/fc) = 0.13862961

and confined core properties:

b = 190.00

$d = 427.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.15907051$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.15907051$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.19522289$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.2282401$
 $Mu = MRc (4.14) = 1.6904E+008$
 $u = su (4.1) = 1.4516822E-005$

 Calculation of ratio l_b/l_d

 Inadequate Lap Length with $l_b/l_d = 0.30$

 Calculation of Mu_1 -

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 1.4516822E-005$
 $Mu = 1.6904E+008$

with full section properties:

$b = 250.00$
 $d = 457.00$
 $d' = 43.00$
 $v = 0.00206425$
 $N = 4716.808$
 $f_c = 20.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01470636$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01470636$
 $w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$
 where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07705054$
 $a_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$
 From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.004064$
 $bw = 500.00$
 effective stress from (A.35), $f_{f,e} = 837.9178$

$f_y = 0.12936483$
 $a_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$
 From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.008128$
 $bw = 250.00$
 effective stress from (A.35), $f_{f,e} = 703.4155$

$R = 40.00$
 Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

ase ((5.4d), TBDY) = 0.05494666

bo = 440.00

ho = 190.00

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 = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158

c = confinement factor = 1.13916

y1 = 0.00129669

sh1 = 0.0044814

ft1 = 373.4467

fy1 = 311.2056

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669

sh2 = 0.0044814

ft2 = 373.4467

fy2 = 311.2056

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669

shv = 0.0044814

ftv = 373.4467

fyv = 311.2056

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

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 $\epsilon_{suv_nominal}$ and γ_v , $\rho_{shv,ftv,fyv}$, it is considered characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

γ_1 , $\rho_{sh1,ft1,fy1}$, are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 311.2056$

with $E_{sv} = E_s = 200000.00$

1 = $\rho_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.11295746$

2 = $\rho_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.11295746$

$v = \rho_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.13862961$

and confined core properties:

$b = 190.00$

$d = 427.00$

$d' = 13.00$

f_{cc} (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = $\rho_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.15907051$

2 = $\rho_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.15907051$

$v = \rho_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.19522289$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

ρ_{su} (4.9) = 0.2282401

$\mu_u = MR_c$ (4.14) = 1.6904E+008

$u = \rho_{su}$ (4.1) = 1.4516822E-005

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{u2+}

Calculation of ultimate curvature ρ_u according to 4.1, Biskinis/Fardis 2013:

$u = 1.4516822E-005$

$\mu_u = 1.6904E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00206425$

$N = 4716.808$

$f_c = 20.00$

cc (5A.5, TBDY) = 0.002

Final value of ρ_{cu} : $\rho_{cu}^* = \text{shear_factor} \cdot \text{Max}(\rho_{cu}, cc) = 0.01470636$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\rho_{cu} = 0.01470636$

ρ_{we} ((5.4c), TBDY) = $\rho_{ase} \cdot \rho_{sh,min} \cdot f_{ywe}/f_{ce} + \text{Min}(\rho_{fx}, \rho_{fy}) = 0.07848902$

where $\rho_f = \rho_{af} \cdot \rho_{pf} \cdot f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\rho_{fx} = 0.07705054$

$\rho_{af} = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\rho_{pf} = 2t_f/b_w = 0.004064$

$b_w = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$\rho_{fy} = 0.12936483$

$\rho_{af} = 0.45253333$

$b = 250.00$

h = 500.00
From EC8 A.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

R = 40.00
Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase \text{ ((5.4d), TBDY)} = 0.05494666$
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
 $fy_{we} = 555.55$
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
 $y1 = 0.00129669$
 $sh1 = 0.0044814$
 $ft1 = 373.4467$
 $fy1 = 311.2056$
 $su1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lou_{,min} = lb/ld = 0.30$
 $su1 = 0.4*esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$
From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,
For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs1 = fs = 311.2056$
with $Es1 = Es = 200000.00$

$y2 = 0.00129669$
 $sh2 = 0.0044814$
 $ft2 = 373.4467$
 $fy2 = 311.2056$
 $su2 = 0.00512$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lou_{,min} = lb/lb_{,min} = 0.30$
 $su2 = 0.4*esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$
From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,
For calculation of $esu2_{nominal}$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs2 = fs = 311.2056$
with $Es2 = Es = 200000.00$
 $yv = 0.00129669$
 $shv = 0.0044814$

$$ftv = 373.4467$$

$$fyv = 311.2056$$

$$suv = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/ld = 0.30$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fsv = fs = 311.2056$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl_{ten}/(b*d) * (fs1/fc) = 0.11295746$$

$$2 = Asl_{com}/(b*d) * (fs2/fc) = 0.11295746$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.13862961$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = Asl_{ten}/(b*d) * (fs1/fc) = 0.15907051$$

$$2 = Asl_{com}/(b*d) * (fs2/fc) = 0.15907051$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.19522289$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < vs, y2$ - LHS eq.(4.5) is satisfied

$$su (4.9) = 0.2282401$$

$$Mu = MRc (4.14) = 1.6904E+008$$

$$u = su (4.1) = 1.4516822E-005$$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of $Mu2$ -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.4516822E-005$$

$$Mu = 1.6904E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00206425$$

$$N = 4716.808$$

$$fc = 20.00$$

$$co (5A.5, TBDY) = 0.002$$

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01470636$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.01470636$$

$$we ((5.4c), TBDY) = ase * sh_{min} * fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.07848902$$

where $f = af * pf * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$fx = 0.07705054$$

af = 0.45253333
b = 500.00
h = 250.00
From EC8 A.4.4.3(6), pf = $2t_f/bw = 0.004064$
bw = 500.00
effective stress from (A.35), ff,e = 837.9178

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), pf = $2t_f/bw = 0.008128$
bw = 250.00
effective stress from (A.35), ff,e = 703.4155

R = 40.00
Effective FRP thickness, tf = $NL*t*Cos(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.05494666
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 = $A_{stir}*ns = 78.53982$
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 = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00129669
sh1 = 0.0044814
ft1 = 373.4467
fy1 = 311.2056
su1 = 0.00512
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 0.30
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 = 311.2056
with Es1 = Es = 200000.00
y2 = 0.00129669
sh2 = 0.0044814
ft2 = 373.4467
fy2 = 311.2056
su2 = 0.00512
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_{b,min} = 0.30$$

$$s_u2 = 0.4 * e_{s_u2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s_u2,nominal} = 0.08$,

For calculation of $e_{s_u2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $f_{s_y2} = f_{s_2}/1.2$, 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.

$$\text{with } f_{s_2} = f_s = 311.2056$$

$$\text{with } E_{s_2} = E_s = 200000.00$$

$$y_v = 0.00129669$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4467$$

$$fy_v = 311.2056$$

$$s_{u_v} = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_d = 0.30$$

$$s_{u_v} = 0.4 * e_{s_{u_v},nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } f_{s_v} = f_s = 311.2056$$

$$\text{with } E_{s_v} = E_s = 200000.00$$

$$1 = A_{s_l,ten}/(b*d)*(f_{s_1}/f_c) = 0.11295746$$

$$2 = A_{s_l,com}/(b*d)*(f_{s_2}/f_c) = 0.11295746$$

$$v = A_{s_l,mid}/(b*d)*(f_{s_v}/f_c) = 0.13862961$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 22.78316$$

$$c_c (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{s_l,ten}/(b*d)*(f_{s_1}/f_c) = 0.15907051$$

$$2 = A_{s_l,com}/(b*d)*(f_{s_2}/f_c) = 0.15907051$$

$$v = A_{s_l,mid}/(b*d)*(f_{s_v}/f_c) = 0.19522289$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.2282401$$

$$M_u = M_{Rc} (4.14) = 1.6904E+008$$

$$u = s_u (4.1) = 1.4516822E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 409432.244$

Calculation of Shear Strength at edge 1, $V_{r1} = 409432.244$

$$V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = k_{nl} * V_{Co10}$$

$$V_{Co10} = 409432.244$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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).

$$= 1 \text{ (normal-weight concrete)}$$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$\mu_u = 8.5689464E-013$$

$$\mu_v = 8.5800179E-032$$

$$d = 0.8 \cdot h = 400.00$$

$$N_u = 4716.808$$

$$A_g = 125000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 279249.888$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 100.00$$

$$V_s \text{ is multiplied by } \phi_{col} = 1.00$$

$$s/d = 0.25$$

$$V_f \text{ ((11-3)-(11.4), ACI 440) } = 240803.347$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$$w_f/s_f = 1 \text{ (FRP strips adjacent to one another).}$$

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.

$$\text{orientation 1: } \theta = \theta_1 = 90^\circ = 90.00$$

$$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = N_L \cdot t / N_{oDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440) } = 457.00$$

$$f_{fe} \text{ ((11-5), ACI 440) } = 259.312$$

$$E_f = 64828.00$$

$$f_{e} = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 297085.704$$

$$b_w = 250.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 409432.244$

$$V_{r2} = V_{col} \text{ ((10.3), ASCE 41-17) } = k_{nl} \cdot V_{col0}$$

$$V_{col0} = 409432.244$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$f'_c = 20.00, \text{ but } f'_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$\mu_u = 8.5689464E-013$$

$$\mu_v = 8.5800179E-032$$

$$d = 0.8 \cdot h = 400.00$$

$$N_u = 4716.808$$

$$A_g = 125000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 279249.888$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 100.00$$

$$V_s \text{ is multiplied by } \phi_{col} = 1.00$$

$$s/d = 0.25$$

$$V_f \text{ ((11-3)-(11.4), ACI 440) } = 240803.347$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$$w_f/s_f = 1 \text{ (FRP strips adjacent to one another).}$$

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: $V_s + V_f \leq 297085.704$

$b_w = 250.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_b/l_d = 0.30$

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, $M = -7.3539E+006$

Shear Force, $V_2 = -2443.62$

Shear Force, $V_3 = 2.2001442E-014$

Axial Force, $F = -4752.437$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 829.3805$

-Compression: $As_{c,com} = 829.3805$

-Middle: $As_{mid} = 1017.876$

Mean Diameter of Tension Reinforcement, $Db_L = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u, R = u = 0.03698037$
 $u = y + p = 0.03698037$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00698037$ ((4.29), Biskinis Phd)
 $M_y = 1.1427E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3009.429
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.6421E+013$
factor = 0.30
Ag = 125000.00
fc' = 20.00
N = 4752.437
 $E_c * I_g = 5.4737E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.0110853E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / l_d)^{2/3}) = 248.9644$
d = 457.00
y = 0.32090703
A = 0.02359497
B = 0.01298321
with pt = 0.00725935
pc = 0.00725935
pv = 0.0089092
N = 4752.437
b = 250.00
" = 0.0940919
 $y_{comp} = 1.1987499E-005$
with fc' (12.3, (ACI 440)) = 20.44423
fc = 20.00
fl = 0.9425867
b = 250.00
h = 500.00
Ag = 125000.00
From (12.9), ACI 440: $k_a = 0.15033165$
g = pt + pc + pv = 0.02342789
rc = 40.00
Ae/Ac = 0.60132659
Effective FRP thickness, $t_f = N L * t * \text{Cos}(\theta_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
fu = 0.01
Ef = 64828.00
Ec = 21019.039
y = 0.31958447
A = 0.0233091
B = 0.01281613
with Es = 200000.00

Calculation of ratio l_b / l_d

Inadequate Lap Length with $l_b / l_d = 0.30$

- Calculation of p -

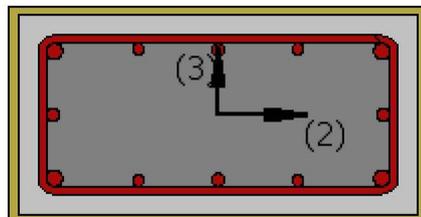
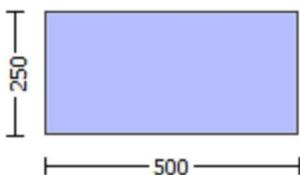
From table 10-8: $p = 0.03$
with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
 shear control ratio $V_{yE}/V_{CoIE} = 0.27523624$
 $d = 457.00$
 $s = 0.00$
 $t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.00$
 $A_v = 157.0796$, 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 $t_f = 2*t_f/b_w$ 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.
 $NUD = 4752.437$
 $Ag = 125000.00$
 $f_{cE} = 20.00$
 $f_{tE} = f_{yIE} = 0.00$
 $pl = Area_{Tot_Long_Rein}/(b*d) = 0.02342789$
 $b = 250.00$
 $d = 457.00$
 $f_{cE} = 20.00$

 End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
 At local axis: 3
 Integration Section: (a)

Calculation No. 13

column C1, Floor 1
 Limit State: Life Safety (data interpolation between analysis steps 1 and 2)
 Analysis: Uniform +X
 Check: Shear capacity VR_d
 Edge: End
 Local Axis: (2)



 Start Of Calculation of Shear Capacity for element: column C1 of floor 1
 At local axis: 2
 Integration Section: (b)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = l_b/l_d = 0.30$

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, $M_a = -7.3539E+006$

Shear Force, $V_a = -2443.62$

EDGE -B-

Bending Moment, $M_b = 21253.373$

Shear Force, $V_b = 2443.62$

BOTH EDGES

Axial Force, $F = -4752.437$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{l,ten} = 829.3805$

-Compression: $As_{l,com} = 829.3805$

-Middle: $As_{l,mid} = 1017.876$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 366313.103$

V_n ((10.3), ASCE 41-17) = $k_n l V_{CoI} = 366313.103$

$V_{CoI} = 366313.103$

kn1 = 1.00
displacement_ductility_demand = 0.097026

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 21253.373$
 $V_u = 2443.62$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4752.437$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 251327.412$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$

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) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = 45^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 457.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 265721.532$

$b_w = 250.00$

displacement_ductility_demand is calculated as δ / y

- Calculation of δ / y for END B -

for rotation axis 3 and integ. section (b)

From analysis, chord rotation $\theta = 6.7515496E-005$

$y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00069585$ ((4.29), Biskinis Phd)

$M_y = 1.1427E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00

From table 10.5, ASCE 41_17: $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 1.6421E+013$

factor = 0.30

$A_g = 125000.00$

$f_c' = 20.00$

$N = 4752.437$

$E_c \cdot I_g = 5.4737E+013$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$

$y_{\text{ten}} = 4.0110853E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 248.9644$

$d = 457.00$

$y = 0.32090703$

A = 0.02359497
B = 0.01298321
with pt = 0.00725935
pc = 0.00725935
pv = 0.0089092
N = 4752.437
b = 250.00
" = 0.0940919
y_comp = 1.1987499E-005
with fc* (12.3, (ACI 440)) = 20.44423
fc = 20.00
fl = 0.9425867
b = 250.00
h = 500.00
Ag = 125000.00
From (12.9), ACI 440: ka = 0.15033165
g = pt + pc + pv = 0.02342789
rc = 40.00
Ae/Ac = 0.60132659
Effective FRP thickness, tf = NL*t*Cos(b1) = 1.016
effective strain from (12.5) and (12.12), efe = 0.004
fu = 0.01
Ef = 64828.00
Ec = 21019.039
y = 0.31958447
A = 0.0233091
B = 0.01281613
with Es = 200000.00

Calculation of ratio lb/ld

Inadequate Lap Length with lb/ld = 0.30

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

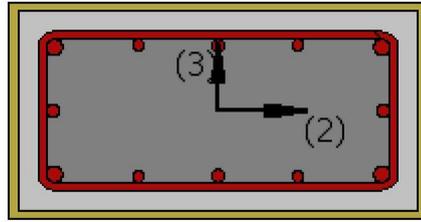
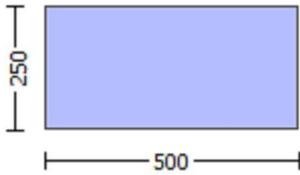
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

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, $\gamma = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$

 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.13916
 Element Length, $L = 3000.00$

Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
 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, $V_a = -3.6206709E-031$
 EDGE -B-
 Shear Force, $V_b = 3.6206709E-031$
 BOTH EDGES
 Axial Force, $F = -4716.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: Asl,t = 0.00

-Compression: Asl,c = 2676.637

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: Asl,ten = 1137.257

-Compression: Asl,com = 1137.257

-Middle: Asl,mid = 402.1239

Calculation of Shear Capacity ratio , $V_e/V_r = 0.1467291$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 52248.951$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 7.8373E+007$

$M_{u1+} = 7.8373E+007$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 7.8373E+007$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 7.8373E+007$

$M_{u2+} = 7.8373E+007$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 7.8373E+007$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of M_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 3.3776478E-005$

$M_u = 7.8373E+007$

with full section properties:

$b = 500.00$

$d = 208.00$

$d' = 42.00$

$v = 0.0022677$

$N = 4716.808$

$f_c = 20.00$

ϕ_c (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01470636$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01470636$

ω_e ((5.4c), TBDY) = $a_s e * \text{sh, min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.07705054$

$a_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.004064$

$b_w = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$

$a_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$

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 = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00129669
sh1 = 0.0044814
ft1 = 373.4467
fy1 = 311.2056
su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669
sh2 = 0.0044814
ft2 = 373.4467
fy2 = 311.2056
su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669
shv = 0.0044814
ftv = 373.4467
fyv = 311.2056
suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

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 $fsv = fs = 311.2056$

with $Esv = Es = 200000.00$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.17015411$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.17015411$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.06016499$$

and confined core properties:

$$b = 440.00$$

$$d = 178.00$$

$$d' = 12.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

c = confinement factor = 1.13916

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.22594519$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.22594519$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.07989222$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs,y2$ - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.27122702$$

$$Mu = MRc (4.14) = 7.8373E+007$$

$$u = su (4.1) = 3.3776478E-005$$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of $Mu1$ -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 3.3776478E-005$$

$$Mu = 7.8373E+007$$

with full section properties:

$$b = 500.00$$

$$d = 208.00$$

$$d' = 42.00$$

$$v = 0.0022677$$

$$N = 4716.808$$

$$fc = 20.00$$

$$co (5A.5, TBDY) = 0.002$$

Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01470636$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01470636$

$$we ((5.4c), TBDY) = ase * sh, \text{min} * fywe / fce + \text{Min}(fx, fy) = 0.07848902$$

where $f = af * pf * ffe / fce$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$fx = 0.07705054$$

$$af = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } ffe = 837.9178$$

$f_y = 0.12936483$
 $a_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$
 $bw = 250.00$
effective stress from (A.35), $ff,e = 703.4155$

 $R = 40.00$
Effective FRP thickness, $tf = NL*t*\cos(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase \text{ ((5.4d), TBDY)} = 0.05494666$
 $bo = 440.00$
 $ho = 190.00$
 $bi2 = 459400.00$
 $psh,min = \text{Min}(psh,x, psh,y) = 0.00314159$

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, $ns = 2.00$
 $bk = 250.00$

 $s = 100.00$
 $fywe = 555.55$
 $fce = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$

$y1 = 0.00129669$
 $sh1 = 0.0044814$
 $ft1 = 373.4467$
 $fy1 = 311.2056$
 $su1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou,min = lb/ld = 0.30$

$su1 = 0.4*esu1_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 311.2056$

with $Es1 = Es = 200000.00$

$y2 = 0.00129669$
 $sh2 = 0.0044814$
 $ft2 = 373.4467$
 $fy2 = 311.2056$
 $su2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou,min = lb/lb,min = 0.30$

$su2 = 0.4*esu2_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 311.2056$

with $E_s2 = E_s = 200000.00$
 $y_v = 0.00129669$
 $sh_v = 0.0044814$
 $ft_v = 373.4467$
 $fy_v = 311.2056$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{u,min} = lb/ld = 0.30$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $fsv = fs = 311.2056$
 with $Esv = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(fs_1/fc) = 0.17015411$
 $2 = A_{sl,com}/(b*d)*(fs_2/fc) = 0.17015411$
 $v = A_{sl,mid}/(b*d)*(fsv/fc) = 0.06016499$
 and confined core properties:
 $b = 440.00$
 $d = 178.00$
 $d' = 12.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b*d)*(fs_1/fc) = 0.22594519$
 $2 = A_{sl,com}/(b*d)*(fs_2/fc) = 0.22594519$
 $v = A_{sl,mid}/(b*d)*(fsv/fc) = 0.07989222$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.27122702$
 $Mu = MRc (4.14) = 7.8373E+007$
 $u = su (4.1) = 3.3776478E-005$

 Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Mu_{2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 3.3776478E-005$
 $Mu = 7.8373E+007$

with full section properties:

$b = 500.00$
 $d = 208.00$
 $d' = 42.00$
 $v = 0.0022677$
 $N = 4716.808$
 $fc = 20.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01470636$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01470636$
 $w_e ((5.4c), TBDY) = ase * sh_{,min} * fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.07848902$

where $f = af*pf*ffe/fce$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$fx = 0.07705054$$

$$af = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } ff,e = 837.9178$$

$$fy = 0.12936483$$

$$af = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff,e = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } tf = NL*t*\text{Cos}(b1) = 1.016$$

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$\text{ase ((5.4d), TBDY) = 0.05494666}$$

$$bo = 440.00$$

$$ho = 190.00$$

$$bi2 = 459400.00$$

$$\text{psh,min} = \text{Min}(\text{psh,x}, \text{psh,y}) = 0.00314159$$

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)

$$\text{psh,x (5.4d)} = 0.00314159$$

$$\text{Ash} = \text{Astir}*ns = 78.53982$$

$$\text{No stirrups, } ns = 2.00$$

$$bk = 500.00$$

$$\text{psh,y (5.4d)} = 0.00628319$$

$$\text{Ash} = \text{Astir}*ns = 78.53982$$

$$\text{No stirrups, } ns = 2.00$$

$$bk = 250.00$$

$$s = 100.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y1 = 0.00129669$$

$$sh1 = 0.0044814$$

$$ft1 = 373.4467$$

$$fy1 = 311.2056$$

$$su1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,\text{min} = lb/ld = 0.30$$

$$su1 = 0.4*esu1_nominal \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_nominal = 0.08,$$

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

$$y1, sh1,ft1,fy1, \text{ are also multiplied by } \text{Min}(1, 1.25*(lb/ld)^{2/3}), \text{ from 10.3.5, ASCE41-17.}$$

$$\text{with } fs1 = fs = 311.2056$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00129669$$

$$sh2 = 0.0044814$$

$$ft2 = 373.4467$$

$$fy2 = 311.2056$$

$$su2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669

shv = 0.0044814

ftv = 373.4467

fyv = 311.2056

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 0.30

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 = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17015411

2 = Asl,com/(b*d)*(fs2/fc) = 0.17015411

v = Asl,mid/(b*d)*(fsv/fc) = 0.06016499

and confined core properties:

b = 440.00

d = 178.00

d' = 12.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = Asl,ten/(b*d)*(fs1/fc) = 0.22594519

2 = Asl,com/(b*d)*(fs2/fc) = 0.22594519

v = Asl,mid/(b*d)*(fsv/fc) = 0.07989222

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.27122702

Mu = MRc (4.14) = 7.8373E+007

u = su (4.1) = 3.3776478E-005

Calculation of ratio lb/ld

Inadequate Lap Length with lb/ld = 0.30

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 3.3776478E-005

Mu = 7.8373E+007

with full section properties:

b = 500.00

d = 208.00

d' = 42.00

v = 0.0022677

N = 4716.808

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01470636$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01470636$

we ((5.4c), TBDY) = $ase * sh_{\min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.07848902$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.07705054

af = 0.45253333

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

bw = 500.00

effective stress from (A.35), $ff_e = 837.9178$

fy = 0.12936483

af = 0.45253333

b = 250.00

h = 500.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

bw = 250.00

effective stress from (A.35), $ff_e = 703.4155$

R = 40.00

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = 0.05494666

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 = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$

c = confinement factor = 1.13916

y1 = 0.00129669

sh1 = 0.0044814

ft1 = 373.4467

fy1 = 311.2056

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = $lb/d = 0.30$

su1 = $0.4 * esu1_{\text{nominal}} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu1_{\text{nominal}} = 0.08,$

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 311.2056$

with $Es1 = Es = 200000.00$

$y2 = 0.00129669$

$sh2 = 0.0044814$

$ft2 = 373.4467$

$fy2 = 311.2056$

$su2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lou, min = lb/lb, min = 0.30$

$su2 = 0.4 \cdot esu2_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 311.2056$

with $Es2 = Es = 200000.00$

$yv = 0.00129669$

$shv = 0.0044814$

$ftv = 373.4467$

$fyv = 311.2056$

$suv = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lou, min = lb/ld = 0.30$

$suv = 0.4 \cdot esuv_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fsv = fs = 311.2056$

with $Esv = Es = 200000.00$

1 = $Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.17015411$

2 = $Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.17015411$

v = $Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.06016499$

and confined core properties:

$b = 440.00$

$d = 178.00$

$d' = 12.00$

$fcc (5A.2, TBDY) = 22.78316$

$cc (5A.5, TBDY) = 0.00339158$

$c = \text{confinement factor} = 1.13916$

1 = $Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.22594519$

2 = $Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.22594519$

v = $Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.07989222$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs, y2$ - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.27122702$

$Mu = MRc (4.14) = 7.8373E+007$

$u = su (4.1) = 3.3776478E-005$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 356091.268$

Calculation of Shear Strength at edge 1, $V_{r1} = 356091.268$

$V_{r1} = V_{Co1} \text{ ((10.3), ASCE 41-17)} = knl * V_{Co10}$

$V_{Co10} = 356091.268$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$M_u = 6.4608054E-012$

$V_u = 3.6206709E-031$

$d = 0.8 * h = 200.00$

$N_u = 4716.808$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 139624.944$

$A_v = 157079.633$

$f_y = 444.44$

$s = 100.00$

V_s is multiplied by $Col = 1.00$

$s/d = 0.50$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 109599.773$

$f = 0.95$, 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) = 208.00

$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$

$b_w = 500.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 356091.268$

$V_{r2} = V_{Co2} \text{ ((10.3), ASCE 41-17)} = knl * V_{Co10}$

$V_{Co10} = 356091.268$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$M_u = 6.4608054E-012$

$V_u = 3.6206709E-031$

$d = 0.8 * h = 200.00$

$N_u = 4716.808$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 139624.944$

$A_v = 157079.633$

$f_y = 444.44$

$s = 100.00$

V_s is multiplied by $Col = 1.00$

$s/d = 0.50$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 109599.773$

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, $tf1 = NL * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 208.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $bw = 500.00$

 End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At local axis: 3

 Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rcrs

Constant Properties

 Knowledge Factor, $\phi = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 * f_{sm} = 555.55$
 #####
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.13916
 Element Length, $L = 3000.00$
 Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou, \min} = 0.30$
 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, $V_a = 8.5800179E-032$

EDGE -B-

Shear Force, $V_b = -8.5800179E-032$

BOTH EDGES

Axial Force, $F = -4716.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 829.3805$

-Compression: $As_{c,com} = 829.3805$

-Middle: $As_{l,mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.27523624$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 112690.591$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.6904E+008$

$Mu_{1+} = 1.6904E+008$, 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

$Mu_{1-} = 1.6904E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.6904E+008$

$Mu_{2+} = 1.6904E+008$, 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

$Mu_{2-} = 1.6904E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.4516822E-005$

$M_u = 1.6904E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00206425$

$N = 4716.808$

$f_c = 20.00$

α_c (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01470636$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01470636$

where ϕ_u ((5.4c), TBDY) = $\alpha_c * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07848902$

where $f = \alpha_f * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.07705054$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$

af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), pf = $2t_f/bw = 0.008128$
bw = 250.00
effective stress from (A.35), ff,e = 703.4155

R = 40.00
Effective FRP thickness, tf = $NL*t*\text{Cos}(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = 0.05494666
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 = $\text{Astir}*ns = 78.53982$
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00628319
Ash = $\text{Astir}*ns = 78.53982$
No stirrups, ns = 2.00
bk = 250.00

s = 100.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00129669
sh1 = 0.0044814
ft1 = 373.4467
fy1 = 311.2056
su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669
sh2 = 0.0044814
ft2 = 373.4467
fy2 = 311.2056
su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669
shv = 0.0044814
ftv = 373.4467
fyv = 311.2056
suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 0.30

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 = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11295746

2 = Asl,com/(b*d)*(fs2/fc) = 0.11295746

v = Asl,mid/(b*d)*(fsv/fc) = 0.13862961

and confined core properties:

b = 190.00

d = 427.00

d' = 13.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = Asl,ten/(b*d)*(fs1/fc) = 0.15907051

2 = Asl,com/(b*d)*(fs2/fc) = 0.15907051

v = Asl,mid/(b*d)*(fsv/fc) = 0.19522289

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

v < vs,y2 - LHS eq.(4.5) is satisfied

su (4.9) = 0.2282401

Mu = MRc (4.14) = 1.6904E+008

u = su (4.1) = 1.4516822E-005

Calculation of ratio lb/ld

Inadequate Lap Length with lb/ld = 0.30

Calculation of Mu1-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.4516822E-005

Mu = 1.6904E+008

with full section properties:

b = 250.00

d = 457.00

d' = 43.00

v = 0.00206425

N = 4716.808

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01470636

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01470636

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+ Min(fx, fy) = 0.07848902

where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.07705054
af = 0.45253333
b = 500.00
h = 250.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.004064
bw = 500.00
effective stress from (A.35), ff,e = 837.9178

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128
bw = 250.00
effective stress from (A.35), ff,e = 703.4155

R = 40.00
Effective FRP thickness, tf = NL*t*cos(b1) = 1.016
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 = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00129669
sh1 = 0.0044814
ft1 = 373.4467
fy1 = 311.2056
su1 = 0.00512
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/d = 0.30
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 = 311.2056
with Es1 = Es = 200000.00
y2 = 0.00129669
sh2 = 0.0044814
ft2 = 373.4467
fy2 = 311.2056
su2 = 0.00512
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669

shv = 0.0044814

ftv = 373.4467

fyv = 311.2056

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/ld = 0.30

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 = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11295746

2 = Asl,com/(b*d)*(fs2/fc) = 0.11295746

v = Asl,mid/(b*d)*(fsv/fc) = 0.13862961

and confined core properties:

b = 190.00

d = 427.00

d' = 13.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

1 = Asl,ten/(b*d)*(fs1/fc) = 0.15907051

2 = Asl,com/(b*d)*(fs2/fc) = 0.15907051

v = Asl,mid/(b*d)*(fsv/fc) = 0.19522289

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.2282401

Mu = MRc (4.14) = 1.6904E+008

u = su (4.1) = 1.4516822E-005

Calculation of ratio lb/ld

Inadequate Lap Length with lb/ld = 0.30

Calculation of Mu2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.4516822E-005

Mu = 1.6904E+008

with full section properties:

b = 250.00

d = 457.00

d' = 43.00

v = 0.00206425

N = 4716.808

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01470636$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01470636$

we ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.07848902$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.07705054

af = 0.45253333

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

bw = 500.00

effective stress from (A.35), $ff_e = 837.9178$

fy = 0.12936483

af = 0.45253333

b = 250.00

h = 500.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

bw = 250.00

effective stress from (A.35), $ff_e = 703.4155$

R = 40.00

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = 0.05494666

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 = $\text{Astir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 500.00

psh,y (5.4d) = 0.00628319

Ash = $\text{Astir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 250.00

s = 100.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$

c = confinement factor = 1.13916

y1 = 0.00129669

sh1 = 0.0044814

ft1 = 373.4467

fy1 = 311.2056

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = $lb/d = 0.30$

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.

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 $f_{s1} = f_s = 311.2056$

with $E_{s1} = E_s = 200000.00$

$y_2 = 0.00129669$

$sh_2 = 0.0044814$

$ft_2 = 373.4467$

$fy_2 = 311.2056$

$su_2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$

$su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$

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 $f_{s2} = f_s/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s2} = f_s = 311.2056$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.00129669$

$sh_v = 0.0044814$

$ft_v = 373.4467$

$fy_v = 311.2056$

$su_v = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30$

$su_v = 0.4 \cdot esu_{v,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu_{v,nominal} = 0.08$,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $esu_{v,nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 311.2056$

with $E_{sv} = E_s = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.11295746$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.11295746$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.13862961$

and confined core properties:

$b = 190.00$

$d = 427.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 22.78316$

$cc (5A.5, TBDY) = 0.00339158$

c = confinement factor = 1.13916

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.15907051$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.15907051$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.19522289$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.2282401$

$\mu_u = MR_c (4.14) = 1.6904E+008$

$u = su (4.1) = 1.4516822E-005$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{u2} -

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.4516822E-005$$

$$\mu = 1.6904E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00206425$$

$$N = 4716.808$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01470636$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01470636$$

$$\phi_{we} \text{ ((5.4c), TBDY)} = a_{se} * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07848902$$

where $\phi = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 837.9178$$

$$\phi_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh, \text{min}} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.00314159$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00628319$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00129669$$

$$sh_1 = 0.0044814$$

$$ft1 = 373.4467$$

$$fy1 = 311.2056$$

$$su1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/ld = 0.30$$

$$su1 = 0.4 * esu1_{nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs1 = fs = 311.2056$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00129669$$

$$sh2 = 0.0044814$$

$$ft2 = 373.4467$$

$$fy2 = 311.2056$$

$$su2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/lb_{,min} = 0.30$$

$$su2 = 0.4 * esu2_{nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs2 = fs = 311.2056$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00129669$$

$$shv = 0.0044814$$

$$ftv = 373.4467$$

$$fyv = 311.2056$$

$$suv = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/ld = 0.30$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fsv = fs = 311.2056$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl_{,ten}/(b*d) * (fs1/fc) = 0.11295746$$

$$2 = Asl_{,com}/(b*d) * (fs2/fc) = 0.11295746$$

$$v = Asl_{,mid}/(b*d) * (fsv/fc) = 0.13862961$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = Asl_{,ten}/(b*d) * (fs1/fc) = 0.15907051$$

$$2 = Asl_{,com}/(b*d) * (fs2/fc) = 0.15907051$$

$$v = Asl_{,mid}/(b*d) * (fsv/fc) = 0.19522289$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs, y2$ - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.2282401$$

$$Mu = MRc (4.14) = 1.6904E+008$$

$$u = su(4.1) = 1.4516822E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 409432.244$

Calculation of Shear Strength at edge 1, $V_{r1} = 409432.244$

$V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l V_{Col0}$

$$V_{Col0} = 409432.244$$

$k_n l = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v f_y d/s$ ' is replaced by ' $V_s + f^* V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$M_u = 8.5689464E-013$$

$$V_u = 8.5800179E-032$$

$$d = 0.8h = 400.00$$

$$N_u = 4716.808$$

$$A_g = 125000.00$$

From (11.5.4.8), ACI 318-14: $V_s = 279249.888$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 100.00$$

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 $V_f(\theta, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = 45^\circ + 90^\circ = 135^\circ$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a)|)$, with:

total thickness per orientation, $t_{f1} = N_L t / N_{Dir} = 1.016$

$d_{fv} = d$ (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: $V_s + V_f \leq 297085.704$

$$b_w = 250.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 409432.244$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l V_{Col0}$

$$V_{Col0} = 409432.244$$

$k_n l = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v f_y d/s$ ' is replaced by ' $V_s + f^* V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$M_u = 8.5689464E-013$$

$$V_u = 8.5800179E-032$$

$$d = 0.8h = 400.00$$

Nu = 4716.808
 Ag = 125000.00
 From (11.5.4.8), ACI 318-14: Vs = 279249.888
 Av = 157079.633
 fy = 444.44
 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) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function Vf(θ , α), is implemented for every different fiber orientation ai,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta_1 = b1 + 90^\circ = 90.00$
 Vf = Min(|Vf(45, θ_1)|, |Vf(-45, θ_1)|), with:
 total thickness per orientation, tf1 = NL*t/NoDir = 1.016
 dfv = d (figure 11.2, ACI 440) = 457.00
 ffe ((11-5), ACI 440) = 259.312
 Ef = 64828.00
 fe = 0.004, from (11.6a), ACI 440
 with fu = 0.01
 From (11-11), ACI 440: Vs + Vf <= 297085.704
 bw = 250.00

 End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At local axis: 2

 Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
 At local axis: 2
 Integration Section: (b)
 Section Type: rcrs

Constant Properties

 Knowledge Factor, $\gamma = 1.00$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00
 Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44
 Concrete Elasticity, Ec = 21019.039
 Steel Elasticity, Es = 200000.00
 Section Height, H = 250.00
 Section Width, W = 500.00
 Cover Thickness, c = 25.00
 Element Length, L = 3000.00
 Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with lb/ld = 0.30
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, t = 1.016
 Tensile Strength, ffu = 1055.00
 Tensile Modulus, Ef = 64828.00
 Elongation, efu = 0.01
 Number of directions, NoDir = 1
 Fiber orientations, bi: 0.00°

Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

Bending Moment, M = -2.5222546E-011
Shear Force, V2 = 2443.62
Shear Force, V3 = -2.2001442E-014
Axial Force, F = -4752.437
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 2676.637
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 1137.257
-Compression: Asl,com = 1137.257
-Middle: Asl,mid = 402.1239
Mean Diameter of Tension Reinforcement, DbL = 16.80

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u,R = * u = 0.03692682$
 $u = y + p = 0.03692682$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00692682$ ((4.29), Biskinis Phd)
 $M_y = 5.6873E+007$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1053E+012$
factor = 0.30
Ag = 125000.00
fc' = 20.00
N = 4752.437
 $E_c * I_g = 1.3684E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 9.2392118E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / d)^{2/3}) = 248.9644$
d = 208.00
y = 0.35224754
A = 0.02592044
B = 0.01565043
with pt = 0.01093516
pc = 0.01093516
pv = 0.00386658
N = 4752.437
b = 500.00
" = 0.20192308
 $y_{comp} = 2.3974177E-005$
with fc' (12.3, (ACI 440)) = 20.44353
fc = 20.00
fl = 0.9425867
b = 500.00
h = 250.00
Ag = 125000.00
From (12.9), ACI 440: ka = 0.15009543
g = pt + pc + pv = 0.02573689
rc = 40.00

$$A_e/A_c = 0.60038173$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \cos(\theta) = 1.016$$

effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 21019.039$$

$$y = 0.35108201$$

$$A = 0.02560639$$

$$B = 0.01546688$$

$$\text{with } E_s = 200000.00$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

- Calculation of ρ -

From table 10-8: $\rho = 0.03$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$

$$\text{shear control ratio } V_y E / V_{col} I_{OE} = 0.1467291$$

$$d = 208.00$$

$$s = 0.00$$

$$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$$

$A_v = 157.0796$, 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.

$$N_{UD} = 4752.437$$

$$A_g = 125000.00$$

$$f_{cE} = 20.00$$

$$f_{ytE} = f_{ylE} = 0.00$$

$$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.02573689$$

$$b = 500.00$$

$$d = 208.00$$

$$f_{cE} = 20.00$$

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 15

column C1, Floor 1

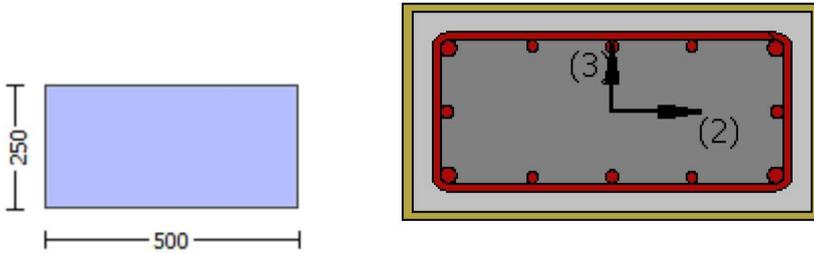
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = l_b/l_d = 0.30$

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 = -4.0780157E-011
Shear Force, Va = 2.2001442E-014
EDGE -B-
Bending Moment, Mb = -2.5222546E-011
Shear Force, Vb = -2.2001442E-014
BOTH EDGES
Axial Force, F = -4752.437
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Asl,t = 0.00
-Compression: Asl,c = 2676.637
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 1137.257
-Compression: Asl,com = 1137.257
-Middle: Asl,mid = 402.1239
Mean Diameter of Tension Reinforcement, DbL,ten = 16.80

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity VR = *Vn = 330375.062
Vn ((10.3), ASCE 41-17) = knl*VCoI0 = 330375.062
VCoI = 330375.062
knl = 1.00
displacement_ductility_demand = 0.00

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' = 16.00, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
M/Vd = 2.00
Mu = 2.5222546E-011
Vu = 2.2001442E-014
d = 0.8*h = 200.00
Nu = 4752.437
Ag = 125000.00
From (11.5.4.8), ACI 318-14: Vs = 125663.706
Av = 157079.633
fy = 400.00
s = 100.00
Vs is multiplied by Col = 1.00
s/d = 0.50
Vf ((11-3)-(11.4), ACI 440) = 109599.773
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) = 208.00
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 <= 265721.532

bw = 500.00

displacement_ductility_demand is calculated as ϕ_y

- Calculation of ϕ_y for END B -
for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta_c = 1.2806903E-022$
 $y = (M_y * L_s / 3) / E_{eff} = 0.00692682$ ((4.29), Biskinis Phd)
 $M_y = 5.6873E+007$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1053E+012$
factor = 0.30
 $A_g = 125000.00$
 $f_c' = 20.00$
 $N = 4752.437$
 $E_c * I_g = 1.3684E+013$

Calculation of Yielding Moment M_y

Calculation of ϕ_y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 9.2392118E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / d)^{2/3}) = 248.9644$
 $d = 208.00$
 $y = 0.35224754$
 $A = 0.02592044$
 $B = 0.01565043$
with $p_t = 0.01093516$
 $p_c = 0.01093516$
 $p_v = 0.00386658$
 $N = 4752.437$
 $b = 500.00$
 $t = 0.20192308$
 $y_{comp} = 2.3974177E-005$
with $f_c' (12.3, (ACI 440)) = 20.44353$
 $f_c = 20.00$
 $f_l = 0.9425867$
 $b = 500.00$
 $h = 250.00$
 $A_g = 125000.00$
From (12.9), ACI 440: $k_a = 0.15009543$
 $g = p_t + p_c + p_v = 0.02573689$
 $r_c = 40.00$
 $A_e / A_c = 0.60038173$
Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.35108201$
 $A = 0.02560639$
 $B = 0.01546688$
with $E_s = 200000.00$

Calculation of ratio l_b / d

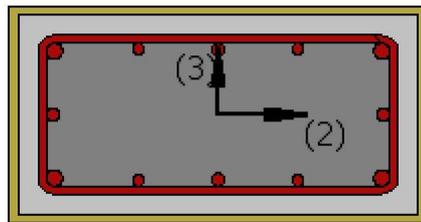
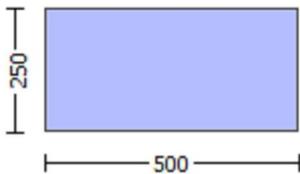
Inadequate Lap Length with $l_b / d = 0.30$

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: Life Safety (data interpolation between analysis steps 1 and 2)
Analysis: Uniform +X
Check: Chord rotation capacity (θ)
Edge: End
Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At Shear local axis: 3
(Bending local axis: 2)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

Section Height, $H = 250.00$
Section Width, $W = 500.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.13916
Element Length, $L = 3000.00$
Secondary Member

Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
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, $V_a = -3.6206709E-031$
EDGE -B-
Shear Force, $V_b = 3.6206709E-031$
BOTH EDGES
Axial Force, $F = -4716.808$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 2676.637$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1137.257$
-Compression: $As_{l,com} = 1137.257$
-Middle: $As_{l,mid} = 402.1239$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.1467291$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 52248.951$
with
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 7.8373E+007$
 $Mu_{1+} = 7.8373E+007$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $Mu_{1-} = 7.8373E+007$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 7.8373E+007$
 $Mu_{2+} = 7.8373E+007$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the the static loading combination
 $Mu_{2-} = 7.8373E+007$, is the ultimate moment strength at the edge 2 of the member in the opposite moment
direction which is defined for the the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 3.3776478E-005$
 $M_u = 7.8373E+007$

with full section properties:
 $b = 500.00$
 $d = 208.00$
 $d' = 42.00$
 $v = 0.0022677$

N = 4716.808

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01470636$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01470636$

we ((5.4c), TBDY) = $ase * sh_{\min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.07848902$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.07705054

af = 0.45253333

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

bw = 500.00

effective stress from (A.35), $ff_e = 837.9178$

fy = 0.12936483

af = 0.45253333

b = 250.00

h = 500.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

bw = 250.00

effective stress from (A.35), $ff_e = 703.4155$

R = 40.00

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = 0.05494666

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 = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$

c = confinement factor = 1.13916

y1 = 0.00129669

sh1 = 0.0044814

ft1 = 373.4467

fy1 = 311.2056

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = $lb/ld = 0.30$

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 $f_{s1} = f_s = 311.2056$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.00129669$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4467$
 $fy_2 = 311.2056$
 $su_2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.30$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 311.2056$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00129669$
 $sh_v = 0.0044814$
 $ft_v = 373.4467$
 $fy_v = 311.2056$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.30$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsy_v = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsy_v = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 311.2056$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.17015411$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.17015411$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.06016499$
 and confined core properties:
 $b = 440.00$
 $d = 178.00$
 $d' = 12.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.22594519$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.22594519$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.07989222$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.27122702$
 $Mu = MRc (4.14) = 7.8373E+007$
 $u = su (4.1) = 3.3776478E-005$

 Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Mu_1 -

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 3.3776478E-005$$

$$Mu = 7.8373E+007$$

with full section properties:

$$b = 500.00$$

$$d = 208.00$$

$$d' = 42.00$$

$$v = 0.0022677$$

$$N = 4716.808$$

$$f_c = 20.00$$

$$\omega (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01470636$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01470636$$

$$\omega_e (5.4c, TBDY) = a_s e * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07848902$$

where $\phi = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 837.9178$$

$$\phi_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s e ((5.4d), TBDY) = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_i^2 = 459400.00$$

$$p_{sh, \text{min}} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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)

$$p_{sh,x} (5.4d) = 0.00314159$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} (5.4d) = 0.00628319$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00129669$$

$$sh_1 = 0.0044814$$

$$f_{t1} = 373.4467$$

$$f_{y1} = 311.2056$$

```

su1 = 0.00512
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/d = 0.30
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 = 311.2056
with Es1 = Es = 200000.00
y2 = 0.00129669
sh2 = 0.0044814
ft2 = 373.4467
fy2 = 311.2056
su2 = 0.00512
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 0.30
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 = 311.2056
with Es2 = Es = 200000.00
yv = 0.00129669
shv = 0.0044814
ftv = 373.4467
fyv = 311.2056
suv = 0.00512
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/d = 0.30
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 = 311.2056
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17015411
2 = Asl,com/(b*d)*(fs2/fc) = 0.17015411
v = Asl,mid/(b*d)*(fsv/fc) = 0.06016499
and confined core properties:
b = 440.00
d = 178.00
d' = 12.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.22594519
2 = Asl,com/(b*d)*(fs2/fc) = 0.22594519
v = Asl,mid/(b*d)*(fsv/fc) = 0.07989222
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.27122702
Mu = MRc (4.14) = 7.8373E+007
u = su (4.1) = 3.3776478E-005

```

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 3.3776478E-005$

$\mu_{2+} = 7.8373E+007$

with full section properties:

$b = 500.00$

$d = 208.00$

$d' = 42.00$

$\nu = 0.0022677$

$N = 4716.808$

$f_c = 20.00$

ω (5A.5, TBDY) = 0.002

Final value of μ_c : $\mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01470636$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.01470636$

ω_e ((5.4c), TBDY) = $\text{ase} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$

where $f = \text{af} * \text{pf} * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.07705054$

$\text{af} = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f/b_w = 0.004064$

$b_w = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$

$\text{af} = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = \text{NL} * t * \text{Cos}(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{f} = 0.015$

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

$A_{sh} = A_{\text{stir}} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 250.00$

$s = 100.00$
 $fy_{we} = 555.55$
 $f_{ce} = 20.00$
 From ((5.A.5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $y_1 = 0.00129669$
 $sh_1 = 0.0044814$
 $ft_1 = 373.4467$
 $fy_1 = 311.2056$
 $su_1 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/d = 0.30$
 $su_1 = 0.4 * esu_1 \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esu_1 \text{ nominal} = 0.08$,
 For calculation of $esu_1 \text{ nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 311.2056$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.00129669$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4467$
 $fy_2 = 311.2056$
 $su_2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/lb, \min = 0.30$
 $su_2 = 0.4 * esu_2 \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esu_2 \text{ nominal} = 0.08$,
 For calculation of $esu_2 \text{ nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 311.2056$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.00129669$
 $sh_v = 0.0044814$
 $ft_v = 373.4467$
 $fy_v = 311.2056$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/d = 0.30$
 $suv = 0.4 * esuv \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esuv \text{ nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv \text{ nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 311.2056$
 with $Es_v = Es = 200000.00$
 $1 = Asl, \text{ten}/(b * d) * (fs_1/fc) = 0.17015411$
 $2 = Asl, \text{com}/(b * d) * (fs_2/fc) = 0.17015411$
 $v = Asl, \text{mid}/(b * d) * (fsv/fc) = 0.06016499$
 and confined core properties:
 $b = 440.00$
 $d = 178.00$
 $d' = 12.00$
 $f_{cc} \text{ (5A.2, TBDY)} = 22.78316$
 $cc \text{ (5A.5, TBDY)} = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl, \text{ten}/(b * d) * (fs_1/fc) = 0.22594519$
 $2 = Asl, \text{com}/(b * d) * (fs_2/fc) = 0.22594519$

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.07989222$$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u(4.9) = 0.27122702$$

$$M_u = M_{Rc}(4.14) = 7.8373E+007$$

$$u = s_u(4.1) = 3.3776478E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u2}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 3.3776478E-005$$

$$M_u = 7.8373E+007$$

with full section properties:

$$b = 500.00$$

$$d = 208.00$$

$$d' = 42.00$$

$$v = 0.0022677$$

$$N = 4716.808$$

$$f_c = 20.00$$

$$\alpha(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \alpha: \alpha^* = \text{shear_factor} \cdot \text{Max}(\alpha, \alpha_c) = 0.01470636$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \alpha_c = 0.01470636$$

$$\alpha_{we}((5.4c), TBDY) = \alpha_{se} \cdot \text{sh}_{, \min} \cdot f_{ywe} / f_{ce} + \text{Min}(\alpha_x, \alpha_y) = 0.07848902$$

where $f = \alpha \cdot \rho_f \cdot f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\alpha_x = 0.07705054$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$\alpha_y = 0.12936483$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL \cdot t \cdot \text{Cos}(\beta_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se}((5.4d), TBDY) = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$\rho_{sh, \min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.00314159$$

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)

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 = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00129669
sh1 = 0.0044814
ft1 = 373.4467
fy1 = 311.2056
su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669
sh2 = 0.0044814
ft2 = 373.4467
fy2 = 311.2056
su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

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 = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669
shv = 0.0044814
ftv = 373.4467
fyv = 311.2056
suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

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 = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17015411

2 = Asl,com/(b*d)*(fs2/fc) = 0.17015411

$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.06016499$
 and confined core properties:
 $b = 440.00$
 $d = 178.00$
 $d' = 12.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22594519$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.22594519$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07989222$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.27122702$
 $Mu = MRc (4.14) = 7.8373E+007$
 $u = su (4.1) = 3.3776478E-005$

 Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

 Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 356091.268$

 Calculation of Shear Strength at edge 1, $V_{r1} = 356091.268$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$
 $V_{Col0} = 356091.268$
 $k_{nl} = 1$ (zero step-static loading)

 NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_{s+} = f * V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $Mu = 6.4608054E-012$
 $Vu = 3.6206709E-031$
 $d = 0.8 * h = 200.00$
 $Nu = 4716.808$
 $Ag = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 139624.944$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 100.00$
 V_s is multiplied by $Col = 1.00$
 $s/d = 0.50$
 $V_f ((11-3)-(11.4), ACI 440) = 109599.773$
 $f = 0.95$, 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) = 208.00
 $f_{fe} ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $bw = 500.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 356091.268$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 356091.268$
 $knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M / Vd = 2.00$
 $\mu_u = 6.4608054E-012$
 $V_u = 3.6206709E-031$
 $d = 0.8 * h = 200.00$
 $N_u = 4716.808$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 139624.944$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 100.00$

V_s is multiplied by $Col = 1.00$
 $s/d = 0.50$

$V_f ((11-3)-(11.4), ACI 440) = 109599.773$
 $f = 0.95$, 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 $V_f(a, \theta)$, 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: $\theta_1 = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 208.00

$f_{fe} ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $bw = 500.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$

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, $V_a = 8.5800179E-032$

EDGE -B-

Shear Force, $V_b = -8.5800179E-032$

BOTH EDGES

Axial Force, $F = -4716.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 829.3805$

-Compression: $As_{l,com} = 829.3805$

-Middle: $As_{l,mid} = 1017.876$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.27523624$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 112690.591$

with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 1.6904E+008$

$\mu_{1+} = 1.6904E+008$, 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

$\mu_{1-} = 1.6904E+008$, 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 1.6904E+008$

$\mu_{2+} = 1.6904E+008$, 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

$\mu_{2-} = 1.6904E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of μ_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.4516822E-005$$

$$\mu = 1.6904E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00206425$$

$$N = 4716.808$$

$$f_c = 20.00$$

$$\alpha (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01470636$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01470636$$

$$\omega_e \text{ ((5.4c), TBDY) } = \alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07848902$$

where $\phi = \alpha * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.07705054$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$\phi_y = 0.12936483$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(\beta_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$\alpha s_e \text{ ((5.4d), TBDY) } = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$\text{psh}_{\min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.00314159$$

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)

$$\text{psh}_x \text{ (5.4d) } = 0.00314159$$

$$A_{sh} = A_{\text{stir}} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$\text{psh}_y \text{ (5.4d) } = 0.00628319$$

$$A_{sh} = A_{\text{stir}} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00129669$$

$$sh_1 = 0.0044814$$

$$ft_1 = 373.4467$$

$$fy_1 = 311.2056$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.30$$

$$s_u1 = 0.4 * e_{su1,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su1,nominal} = 0.08$,

For calculation of $e_{su1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $f_{sy1} = f_{s1}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s1} = f_s = 311.2056$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.00129669$$

$$sh_2 = 0.0044814$$

$$ft_2 = 373.4467$$

$$fy_2 = 311.2056$$

$$s_u2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$$

$$s_u2 = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su2,nominal} = 0.08$,

For calculation of $e_{su2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s2} = f_s = 311.2056$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.00129669$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4467$$

$$fy_v = 311.2056$$

$$s_{uv} = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.30$$

$$s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY
For calculation of $e_{suv,nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{sv} = f_s = 311.2056$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.11295746$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.11295746$$

$$v = A_{s1,mid}/(b*d) * (f_{sv}/f_c) = 0.13862961$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 22.78316$$

$$c_c (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.15907051$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.15907051$$

$$v = A_{s1,mid}/(b*d) * (f_{sv}/f_c) = 0.19522289$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

---->

$$s_u (4.9) = 0.2282401$$

$$\mu_u = M_{Rc} (4.14) = 1.6904E+008$$

$$u = s_u (4.1) = 1.4516822E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_1

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.4516822E-005$$

$$\mu_1 = 1.6904E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00206425$$

$$N = 4716.808$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01470636$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01470636$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$$

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)

$$p_{sh,x} \text{ (5.4d)} = 0.00314159$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00628319$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 100.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00339158$

$$c = \text{confinement factor} = 1.13916$$

$$y1 = 0.00129669$$

$$sh1 = 0.0044814$$

$$ft1 = 373.4467$$

$$fy1 = 311.2056$$

$$su1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.30$$

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs1 = fs = 311.2056$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00129669$$

$$sh2 = 0.0044814$$

$$ft2 = 373.4467$$

$$fy2 = 311.2056$$

$$su2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.30$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs2 = fs = 311.2056$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00129669$$

$$shv = 0.0044814$$

$$ftv = 373.4467$$

$$fyv = 311.2056$$

$$suv = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.30$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fsv = fs = 311.2056$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.11295746$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.11295746$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.13862961$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.15907051$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.15907051$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.19522289$$

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) = 0.2282401

$M_u = M_{Rc}$ (4.14) = 1.6904E+008

$u = s_u$ (4.1) = 1.4516822E-005

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 1.4516822E-005$

$M_u = 1.6904E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00206425$

$N = 4716.808$

$f_c = 20.00$

α (5A.5, TBDY) = 0.002

Final value of α : $\alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01470636$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\alpha_c = 0.01470636$

ω ((5.4c), TBDY) = $\alpha^* \cdot \text{sh_min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$

where $f = \alpha^* \cdot p_f \cdot f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07705054$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

 $f_y = 0.12936483$

$\alpha_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

 $R = 40.00$

Effective FRP thickness, $t_f = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

α_{se} ((5.4d), TBDY) = 0.05494666

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00314159$

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 = 555.55
fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00129669
sh1 = 0.0044814

ft1 = 373.4467
fy1 = 311.2056

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 0.30

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 = 311.2056

with Es1 = Es = 200000.00

y2 = 0.00129669
sh2 = 0.0044814

ft2 = 373.4467
fy2 = 311.2056

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

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/ld)^ 2/3), from 10.3.5, ASCE41-17.

with fs2 = fs = 311.2056

with Es2 = Es = 200000.00

yv = 0.00129669
shv = 0.0044814

ftv = 373.4467
fyv = 311.2056

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 0.30

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 = 311.2056

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11295746

2 = Asl,com/(b*d)*(fs2/fc) = 0.11295746

v = Asl,mid/(b*d)*(fsv/fc) = 0.13862961

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.15907051$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.15907051$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.19522289$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.2282401$$

$$\mu_u = MR_c (4.14) = 1.6904E+008$$

$$u = s_u (4.1) = 1.4516822E-005$$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_{u2} -

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.4516822E-005$$

$$\mu_u = 1.6904E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00206425$$

$$N = 4716.808$$

$$f_c = 20.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01470636$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01470636$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07848902$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$a_s e ((5.4d), TBDY) = 0.05494666$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh, min} = \text{Min}(p_{sh, x}, p_{sh, y}) = 0.00314159$$

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)

$$p_{sh, x} (5.4d) = 0.00314159$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 500.00$$

$$p_{sh, y} (5.4d) = 0.00628319$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirrups, } n_s = 2.00$$

$$b_k = 250.00$$

$$s = 100.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From } ((5.A.5), TBDY), TBDY: c_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00129669$$

$$sh_1 = 0.0044814$$

$$ft_1 = 373.4467$$

$$fy_1 = 311.2056$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o, min} = l_b/l_d = 0.30$$

$$su_1 = 0.4 * esu_{1, nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs_1 = fs = 311.2056$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00129669$$

$$sh_2 = 0.0044814$$

$$ft_2 = 373.4467$$

$$fy_2 = 311.2056$$

$$su_2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o, min} = l_b/l_{b, min} = 0.30$$

$$su_2 = 0.4 * esu_{2, nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{2, nominal} = 0.08$,

For calculation of $esu_{2, nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 311.2056$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00129669$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4467$$

$$fy_v = 311.2056$$

$$su_v = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o, min} = l_b/l_d = 0.30$$

$$su_v = 0.4 * esu_{v, nominal} ((5.5), TBDY) = 0.032$$

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 $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 311.2056$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.11295746$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.11295746$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.13862961$

and confined core properties:

$b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 f_{cc} (5A.2, TBDY) = 22.78316
 cc (5A.5, TBDY) = 0.00339158
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.15907051$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.15907051$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.19522289$

Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->
 μ_u (4.9) = 0.2282401
 $M_u = M_{Rc}$ (4.14) = 1.6904E+008
 $u = \mu_u$ (4.1) = 1.4516822E-005

 Calculation of ratio l_b/l_d

 Inadequate Lap Length with $l_b/l_d = 0.30$

 Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 409432.244$

 Calculation of Shear Strength at edge 1, $V_{r1} = 409432.244$
 $V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 409432.244$
 $k_{nl} = 1$ (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).

 $\beta = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 8.5689464E-013$
 $V_u = 8.5800179E-032$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4716.808$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 279249.888$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 100.00$
 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 $(\cot \theta + \csc \theta) \sin \theta$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation θ_i ,

as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta = 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
total thickness per orientation, $t_{f1} = NL * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 409432.244$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Col0}$
 $V_{Col0} = 409432.244$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)
 $f'_c = 20.00$, but $f'_c \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M / Vd = 2.00$
 $\mu_u = 8.5689464E-013$
 $\nu_u = 8.5800179E-032$
 $d = 0.8 * h = 400.00$
 $N_u = 4716.808$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 279249.888$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 100.00$
 V_s is multiplied by $\lambda_{Col} = 1.00$
 $s/d = 0.25$

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 $(\cot \theta + \csc \theta) \sin \theta$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \lambda)$, 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: $\theta = 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
total thickness per orientation, $t_{f1} = NL * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $b_w = 250.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
At local axis: 3
Integration Section: (b)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\phi = 1.00$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_b/l_d = 0.30$
 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, $M = 21253.373$
 Shear Force, $V_2 = 2443.62$
 Shear Force, $V_3 = -2.2001442E-014$
 Axial Force, $F = -4752.437$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{sl,t} = 0.00$
 -Compression: $A_{sl,c} = 2676.637$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{sl,ten} = 829.3805$
 -Compression: $A_{sl,com} = 829.3805$
 -Middle: $A_{sl,mid} = 1017.876$
 Mean Diameter of Tension Reinforcement, $Db_L = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \phi \cdot u = 0.03069585$
 $u = y + p = 0.03069585$

- Calculation of y -

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00069585$ ((4.29), Biskinis Phd)
 $M_y = 1.1427E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 1.6421E+013$
 factor = 0.30
 $A_g = 125000.00$
 $f_c' = 20.00$
 $N = 4752.437$
 $E_c \cdot I_g = 5.4737E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$$

$$y_{\text{ten}} = 4.0110853\text{E-}006$$

$$\text{with } ((10.1), \text{ASCE 41-17}) f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/l_d)^{2/3}) = 248.9644$$

$$d = 457.00$$

$$y = 0.32090703$$

$$A = 0.02359497$$

$$B = 0.01298321$$

$$\text{with } p_t = 0.00725935$$

$$p_c = 0.00725935$$

$$p_v = 0.0089092$$

$$N = 4752.437$$

$$b = 250.00$$

$$" = 0.0940919$$

$$y_{\text{comp}} = 1.1987499\text{E-}005$$

$$\text{with } f_c^* (12.3, (\text{ACI 440})) = 20.44423$$

$$f_c = 20.00$$

$$f_l = 0.9425867$$

$$b = 250.00$$

$$h = 500.00$$

$$A_g = 125000.00$$

$$\text{From } (12.9), \text{ACI 440: } k_a = 0.15033165$$

$$g = p_t + p_c + p_v = 0.02342789$$

$$r_c = 40.00$$

$$A_e/A_c = 0.60132659$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cdot \text{Cos}(b_1) = 1.016$$

$$\text{effective strain from } (12.5) \text{ and } (12.12), e_{fe} = 0.004$$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 21019.039$$

$$y = 0.31958447$$

$$A = 0.0233091$$

$$B = 0.01281613$$

$$\text{with } E_s = 200000.00$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

- Calculation of p -

From table 10-8: $p = 0.03$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$

$$\text{shear control ratio } V_y E / V_{CoI} E = 0.27523624$$

$$d = 457.00$$

$$s = 0.00$$

$$t = A_v / (b_w \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00$$

$$A_v = 157.0796, \text{ is the total area of all stirrups parallel to loading (shear) direction}$$

$$b_w = 250.00$$

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ is implemented to account for FRP contribution

where $f = 2 \cdot t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

$$N_{UD} = 4752.437$$

$$A_g = 125000.00$$

$$f_c E = 20.00$$

$$f_{yt} E = f_{yl} E = 0.00$$

$$p_l = \text{Area}_{\text{Tot_Long_Rein}} / (b \cdot d) = 0.02342789$$

$$b = 250.00$$

$$d = 457.00$$

$$f_c E = 20.00$$

· End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
· At local axis: 3
· Integration Section: (b)
