

Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

column C1, Floor 1

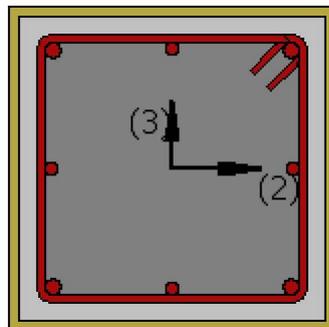
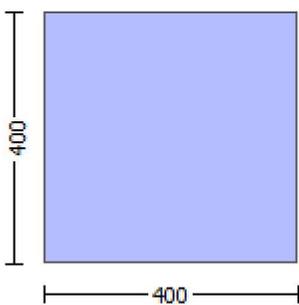
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (2)



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

At local axis: 2

Integration Section: (a)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 0.95$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

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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, $f_s = f_{sm} = 444.4444$

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Section Height, $H = 400.00$

Section Width, $W = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $M_a = -1.3563E+007$

Shear Force, $V_a = -4519.381$

EDGE -B-

Bending Moment, $M_b = 0.1333213$

Shear Force, $V_b = 4519.381$

BOTH EDGES

Axial Force, $F = -5925.123$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression: $A_{sl,c} = 1231.504$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

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

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 384262.188$

V_n ((10.3), ASCE 41-17) = $k_n l V_{CoI} = 404486.513$

$V_{CoI} = 404486.513$

$k_n l = 1.00$

displacement_ductility_demand = 0.04959002

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

= 1 (normal-weight concrete)

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

$M/Vd = 4.00$

$M_u = 1.3563E+007$

$V_u = 4519.381$

$d = 0.8 \cdot h = 320.00$
 $Nu = 5925.123$
 $Ag = 160000.00$
 From (11.5.4.8), ACI 318-14: $Vs = 201061.93$
 $Av = 157079.633$
 $fy = 400.00$
 $s = 100.00$
 Vs is multiplied by $Col = 1.00$
 $s/d = 0.3125$
 Vf ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \csc)\sin\alpha$ which is more a generalised expression,
 where α is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(\alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\alpha = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, \alpha)|, |Vf(-45, \alpha)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / \text{NoDir} = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 357.00
 ffe ((11-5), ACI 440) = 259.312
 $Ef = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.01$
 From (11-11), ACI 440: $Vs + Vf \leq 340123.561$
 $bw = 400.00$

 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 $\theta = 0.0002841$
 $y = (My \cdot Ls / 3) / Eleff = 0.00572891$ ((4.29), Biskinis Phd)
 $My = 7.7038E+007$
 $Ls = M/V$ (with $Ls > 0.1 \cdot L$ and $Ls < 2 \cdot L$) = 3001.112
 From table 10.5, ASCE 41_17: $Eleff = \text{factor} \cdot Ec \cdot Ig = 1.3452E+013$
 $\text{factor} = 0.30$
 $Ag = 160000.00$
 $fc' = 20.00$
 $N = 5925.123$
 $Ec \cdot Ig = 4.4841E+013$

 Calculation of Yielding Moment My

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

 $y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.8497530E-006$
 with ((10.1), ASCE 41-17) $fy = \text{Min}(fy, 1.25 \cdot fy \cdot (lb/d)^{2/3}) = 248.9669$
 $d = 357.00$
 $y = 0.28100837$
 $A = 0.01459862$
 $B = 0.00825179$
 with $pt = 0.00580799$
 $pc = 0.00580799$
 $pv = 0.00281599$
 $N = 5925.123$
 $b = 400.00$
 $\alpha = 0.12044818$
 $y_{comp} = 1.8620192E-005$
 with $fc' = 20.00$ (12.3, (ACI 440)) = 21.65599
 $fc = 20.00$

$f_l = 0.93147527$
 $b = 400.00$
 $h = 400.00$
 $A_g = 160000.00$
 From (12.9), ACI 440: $k_a = 0.56708553$
 $g = p_t + p_c + p_v = 0.01443197$
 $rc = 40.00$
 $A_e/A_c = 0.56708553$
 Effective FRP thickness, $t_f = NL * t * \cos(\theta) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.27898785$
 $A = 0.0143201$
 $B = 0.00808514$
 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

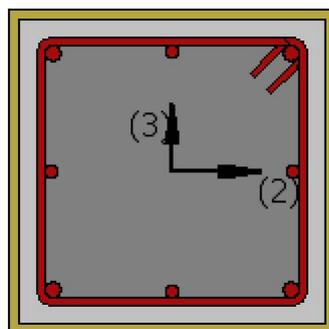
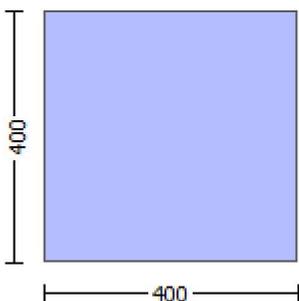
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

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, $\phi = 0.95$

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

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Section Height, $H = 400.00$

Section Width, $W = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.21173

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $V_a = -6.9434686E-031$

EDGE -B-

Shear Force, $V_b = 6.9434686E-031$

BOTH EDGES

Axial Force, $F = -5926.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl} = 0.00$

-Compression: $A_{slc} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Calculation of Shear Capacity ratio, $V_e/V_r = 0.14050197$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 73630.246$

with

$$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.1045E+008$$

$M_{u1+} = 1.1045E+008$, 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

$M_{u1-} = 1.1045E+008$, 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

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.1045E+008$$

$M_{u2+} = 1.1045E+008$, 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

$M_{u2-} = 1.1045E+008$, 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:

$$\phi_u = 1.7976030E-005$$

$$M_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

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

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

$$\phi_{we} \text{ ((5.4c), TBDY)} = \alpha_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.14357935$$

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

$$\phi_{fx} = 0.11712639$$

$$\alpha_{sf} = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_{pf} = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$\phi_{fy} = 0.11712639$$

$$\alpha_{sf} = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_{pf} = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TBDY)} = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$\text{psh}_{\min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.00392699$$

$$\text{psh}_x \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$\text{psh}_y \text{ (5.4d)} = 0.00392699$$

Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
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 $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00
d = 327.00
d' = 13.00

fcc (5A.2, TBDY) = 24.23468

cc (5A.5, TBDY) = 0.00411734

c = confinement factor = 1.21173

1 = $Asl,ten/(b*d)*(fs1/fc) = 0.1160777$

2 = $Asl,com/(b*d)*(fs2/fc) = 0.1160777$

v = $Asl,mid/(b*d)*(fsv/fc) = 0.0562801$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

su (4.9) = 0.2021744

Mu = MRc (4.14) = 1.1045E+008

u = su (4.1) = 1.7976030E-005

Calculation of ratio lb/l_d

Inadequate Lap Length with lb/l_d = 0.30

Calculation of Mu1-

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

u = 1.7976030E-005

Mu = 1.1045E+008

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00207526

N = 5926.932

fc = 20.00

co (5A.5, TBDY) = 0.002

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

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

From (5.4b), TBDY: cu = 0.018

we ((5.4c), TBDY) = $ase * sh,min*fywe/fce + Min(fx, fy) = 0.14357935$

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

fx = 0.11712639

af = 0.57333333

b = 400.00

h = 400.00

From EC8 A.4.4.3(6), pf = $2tf/bw = 0.00508$

bw = 400.00

effective stress from (A.35), ff,e = 804.2922

fy = 0.11712639

af = 0.57333333

b = 400.00

h = 400.00

From EC8 A.4.4.3(6), pf = $2tf/bw = 0.00508$

bw = 400.00

effective stress from (A.35), ff,e = 804.2922

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) = 0.24250288

bo = 340.00

ho = 340.00

bi2 = 462400.00

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00392699$$

$$psh,x (5.4d) = 0.00392699$$

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

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

$$bk = 400.00$$

$$psh,y (5.4d) = 0.00392699$$

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

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

$$bk = 400.00$$

$$s = 100.00$$

$$fywe = 555.5556$$

$$fce = 20.00$$

$$\text{From } ((5.A5), \text{ TBDY}), \text{ TBDY: } cc = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$y1 = 0.0012967$$

$$sh1 = 0.0044814$$

$$ft1 = 373.4504$$

$$fy1 = 311.2087$$

$$su1 = 0.00512$$

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

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

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

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

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

$$\text{with } fs1 = fs = 311.2087$$

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

$$y2 = 0.0012967$$

$$sh2 = 0.0044814$$

$$ft2 = 373.4504$$

$$fy2 = 311.2087$$

$$su2 = 0.00512$$

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

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

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

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

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

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

$$\text{with } fs2 = fs = 311.2087$$

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

$$yv = 0.0012967$$

$$shv = 0.0044814$$

$$ftv = 373.4504$$

$$fyv = 311.2087$$

$$suv = 0.00512$$

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

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

$$suv = 0.4 * esuv_nominal ((5.5), \text{ TBDY}) = 0.032$$

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

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

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

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

$$\text{with } fsv = fs = 311.2087$$

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

$$1 = \text{Asl,ten}/(b*d) * (fs1/fc) = 0.09037478$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09037478$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.04381808$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 24.23468$$

$$c_c (5A.5, TBDY) = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1160777$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1160777$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.2021744$$

$$M_u = M_{Rc} (4.14) = 1.1045E+008$$

$$u = s_u (4.1) = 1.7976030E-005$$

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:

$$u = 1.7976030E-005$$

$$M_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

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

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

$$w_e \text{ ((5.4c), TBDY) } = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$$

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

$$f_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$f_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$R = 40.00$$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} ((5.4d), TBDY) = 0.24250288$

$b_o = 340.00$

$h_o = 340.00$

$b_{i2} = 462400.00$

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$

$p_{sh,x} (5.4d) = 0.00392699$

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

No stirrups, $n_s = 2.00$

$b_k = 400.00$

$p_{sh,y} (5.4d) = 0.00392699$

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

No stirrups, $n_s = 2.00$

$b_k = 400.00$

$s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A.5), TBDY), TBDY: $cc = 0.00411734$

$c = \text{confinement factor} = 1.21173$

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

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

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

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

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 $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0012967$

$sh_2 = 0.0044814$

$ft_2 = 373.4504$

$fy_2 = 311.2087$

$su_2 = 0.00512$

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 $fsy_2 = fs_2/1.2$, 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 $fs_2 = fs = 311.2087$

with $Es_2 = Es = 200000.00$

$y_v = 0.0012967$

$sh_v = 0.0044814$

$ft_v = 373.4504$

$fy_v = 311.2087$

$su_v = 0.00512$

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: $esuv_nominal = 0.08$,
 considering characteristic value $fsv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 311.2087$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b \cdot d) \cdot (fs1/fc) = 0.09037478$
 $2 = Asl,com/(b \cdot d) \cdot (fs2/fc) = 0.09037478$
 $v = Asl,mid/(b \cdot d) \cdot (fsv/fc) = 0.04381808$

and confined core properties:

$b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 fcc (5A.2, TBDY) = 24.23468
 cc (5A.5, TBDY) = 0.00411734
 $c =$ confinement factor = 1.21173
 $1 = Asl,ten/(b \cdot d) \cdot (fs1/fc) = 0.1160777$
 $2 = Asl,com/(b \cdot d) \cdot (fs2/fc) = 0.1160777$
 $v = Asl,mid/(b \cdot d) \cdot (fsv/fc) = 0.0562801$

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

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

--->
 su (4.9) = 0.2021744
 $Mu = MRc$ (4.14) = 1.1045E+008
 $u = su$ (4.1) = 1.7976030E-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:

$u = 1.7976030E-005$
 $Mu = 1.1045E+008$

with full section properties:

$b = 400.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00207526$
 $N = 5926.932$
 $fc = 20.00$
 co (5A.5, TBDY) = 0.002

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

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

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

we ((5.4c), TBDY) = $ase \cdot sh, min \cdot fywe/fce + Min(fx, fy) = 0.14357935$

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

$fx = 0.11712639$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A4.4.3(6), $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $ffe = 804.2922$

$fy = 0.11712639$

af = 0.57333333
b = 400.00
h = 400.00
From EC8 A.4.4.3(6), pf = $2t_f/bw = 0.00508$
bw = 400.00
effective stress from (A.35), ff,e = 804.2922

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) = 0.24250288
bo = 340.00
ho = 340.00
bi2 = 462400.00
psh,min = $Min(psh,x, psh,y) = 0.00392699$

psh,x (5.4d) = 0.00392699
Ash = $Astir*ns = 78.53982$
No stirups, ns = 2.00
bk = 400.00

psh,y (5.4d) = 0.00392699
Ash = $Astir*ns = 78.53982$
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173
y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814

$$ftv = 373.4504$$

$$fyv = 311.2087$$

$$suv = 0.00512$$

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

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

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

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.

$$\text{with } fsv = fs = 311.2087$$

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

$$1 = Asl_{ten}/(b*d)*(fs1/fc) = 0.09037478$$

$$2 = Asl_{com}/(b*d)*(fs2/fc) = 0.09037478$$

$$v = Asl_{mid}/(b*d)*(fsv/fc) = 0.04381808$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 24.23468$$

$$cc (5A.5, TBDY) = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = Asl_{ten}/(b*d)*(fs1/fc) = 0.1160777$$

$$2 = Asl_{com}/(b*d)*(fs2/fc) = 0.1160777$$

$$v = Asl_{mid}/(b*d)*(fsv/fc) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

$$su (4.9) = 0.2021744$$

$$Mu = MRc (4.14) = 1.1045E+008$$

$$u = su (4.1) = 1.7976030E-005$$

Calculation of ratio lb/d

Inadequate Lap Length with $lb/d = 0.30$

Calculation of Shear Strength $Vr = \text{Min}(Vr1, Vr2) = 524051.339$

Calculation of Shear Strength at edge 1, $Vr1 = 524051.339$

$$Vr1 = VCol ((10.3), ASCE 41-17) = knl * VCol0$$

$$VCol0 = 524051.339$$

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

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

= 1 (normal-weight concrete)

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

$$M/Vd = 2.00$$

$$Mu = 1.8671199E-011$$

$$Vu = 6.9434686E-031$$

$$d = 0.8 * h = 320.00$$

$$Nu = 5926.932$$

$$Ag = 160000.00$$

From (11.5.4.8), ACI 318-14: $Vs = 223402.144$

$$Av = 157079.633$$

$$fy = 444.4444$$

$$s = 100.00$$

Vs is multiplied by Col = 1.00

$$s/d = 0.3125$$

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

f = 0.95, for fully-wrapped sections

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

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

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

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

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

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

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 380269.701$$

$$b_w = 400.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 524051.339$

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

$$V_{Col0} = 524051.339$$

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

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

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

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

$$M/Vd = 2.00$$

$$\mu_u = 1.8671199E-011$$

$$\nu_u = 6.9434686E-031$$

$$d = 0.8 * h = 320.00$$

$$N_u = 5926.932$$

$$A_g = 160000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 223402.144$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs is multiplied by Col = 1.00

$$s/d = 0.3125$$

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

f = 0.95, for fully-wrapped sections

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

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

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

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

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

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

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 380269.701$$

$$b_w = 400.00$$

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

At local axis: 3

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

Constant Properties

Knowledge Factor, $\phi = 0.95$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

Section Height, $H = 400.00$
Section Width, $W = 400.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.21173
Element Length, $L = 3000.00$
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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: 2
EDGE -A-
Shear Force, $V_a = 4.2515079E-047$
EDGE -B-
Shear Force, $V_b = -4.2515079E-047$
BOTH EDGES
Axial Force, $F = -5926.932$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten} = 829.3805$
-Compression: $A_{st,com} = 829.3805$
-Middle: $A_{st,mid} = 402.1239$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.14050197$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 73630.246$

with
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 1.1045E+008$
 $\mu_{1+} = 1.1045E+008$, 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
 $\mu_{1-} = 1.1045E+008$, 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
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 1.1045E+008$
 $\mu_{2+} = 1.1045E+008$, 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
 $\mu_{2-} = 1.1045E+008$, 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:

$\mu = 1.7976030E-005$
 $M_u = 1.1045E+008$

 with full section properties:

$b = 400.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00207526$
 $N = 5926.932$
 $f_c = 20.00$
 $\alpha (5A.5, \text{TBDY}) = 0.002$
 Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.018$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\mu_c = 0.018$
 $\mu_{cc} ((5.4c), \text{TBDY}) = \alpha \cdot \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$
 where $f = \alpha * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.11712639$
 $\alpha_f = 0.57333333$
 $b = 400.00$
 $h = 400.00$
 From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$
 $b_w = 400.00$
 effective stress from (A.35), $f_{fe} = 804.2922$

 $f_y = 0.11712639$
 $\alpha_f = 0.57333333$
 $b = 400.00$
 $h = 400.00$
 From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$
 $b_w = 400.00$
 effective stress from (A.35), $f_{fe} = 804.2922$

 $R = 40.00$
 Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $\alpha_{se} ((5.4d), \text{TBDY}) = 0.24250288$
 $b_o = 340.00$
 $h_o = 340.00$
 $b_{i2} = 462400.00$
 $p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$

 $p_{sh,x} (5.4d) = 0.00392699$
 $A_{sh} = A_{stir} * n_s = 78.53982$
 No stirups, $n_s = 2.00$
 $b_k = 400.00$

psh,y (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 24.23468

$$cc \text{ (5A.5, TBDY)} = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = \text{Asl,ten}/(b*d)*(fs1/fc) = 0.1160777$$

$$2 = \text{Asl,com}/(b*d)*(fs2/fc) = 0.1160777$$

$$v = \text{Asl,mid}/(b*d)*(fsv/fc) = 0.0562801$$

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

--->

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

--->

$$su \text{ (4.9)} = 0.2021744$$

$$\text{Mu} = \text{MRc (4.14)} = 1.1045\text{E}+008$$

$$u = su \text{ (4.1)} = 1.7976030\text{E}-005$$

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:

$$u = 1.7976030\text{E}-005$$

$$\text{Mu} = 1.1045\text{E}+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$fc = 20.00$$

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

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

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

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

$$we \text{ ((5.4c), TBDY)} = ase * sh, \min * fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.14357935$$

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

$$fx = 0.11712639$$

$$af = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ff,e = 804.2922$$

$$fy = 0.11712639$$

$$af = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ff,e = 804.2922$$

$$R = 40.00$$

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

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = 0.24250288$$

$$bo = 340.00$$

$$ho = 340.00$$

bi2 = 462400.00
psh,min = Min(psh,x , psh,y) = 0.00392699

psh,x (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

psh,y (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
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 = 311.2087

with Esv = Es = 200000.00

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.09037478$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09037478$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.04381808$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 24.23468$$

$$c_c (5A.5, TBDY) = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1160777$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1160777$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.2021744$$

$$\mu_u = M_{Rc} (4.14) = 1.1045E+008$$

$$u = s_u (4.1) = 1.7976030E-005$$

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:

$$u = 1.7976030E-005$$

$$\mu_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

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

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

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$$

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

$$f_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$f_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

R = 40.00
Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase((5.4d), TBDY) = 0.24250288$
 $bo = 340.00$
 $ho = 340.00$
 $bi2 = 462400.00$
 $psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00392699$

 $psh_{,x}(5.4d) = 0.00392699$
 $Ash = Astir \cdot ns = 78.53982$
No stirrups, $ns = 2.00$
 $bk = 400.00$

 $psh_{,y}(5.4d) = 0.00392699$
 $Ash = Astir \cdot ns = 78.53982$
No stirrups, $ns = 2.00$
 $bk = 400.00$

 $s = 100.00$
 $fy_{we} = 555.5556$
 $f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00411734$
 $c = \text{confinement factor} = 1.21173$

$y_1 = 0.0012967$
 $sh_1 = 0.0044814$
 $ft_1 = 373.4504$
 $fy_1 = 311.2087$
 $su_1 = 0.00512$

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

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

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

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

with $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0012967$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4504$
 $fy_2 = 311.2087$
 $su_2 = 0.00512$

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

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

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

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

with $fs_2 = fs = 311.2087$

with $Es_2 = Es = 200000.00$

$y_v = 0.0012967$
 $sh_v = 0.0044814$
 $ft_v = 373.4504$
 $fy_v = 311.2087$
 $suv = 0.00512$

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 $fsyv = fsv/1.2$, 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 $fsv = fs = 311.2087$

with $Esv = Es = 200000.00$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 24.23468$$

$$cc (5A.5, TBDY) = 0.00411734$$

c = confinement factor = 1.21173

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.1160777$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.1160777$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su (4.9) = 0.2021744$$

$$Mu = MRc (4.14) = 1.1045E+008$$

$$u = su (4.1) = 1.7976030E-005$$

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:

$$u = 1.7976030E-005$$

$$Mu = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$fc = 20.00$$

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

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

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

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

$$we ((5.4c), TBDY) = ase * sh,min * fywe / fce + Min(fx, fy) = 0.14357935$$

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

$$fx = 0.11712639$$

$$af = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ffe = 804.2922$$

$f_y = 0.11712639$
 $a_f = 0.57333333$
 $b = 400.00$
 $h = 400.00$
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$
 $bw = 400.00$
effective stress from (A.35), $ff,e = 804.2922$

$R = 40.00$
Effective FRP thickness, $tf = NL*t*\cos(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase \text{ ((5.4d), TBDY)} = 0.24250288$
 $bo = 340.00$
 $ho = 340.00$
 $bi2 = 462400.00$
 $psh,min = \text{Min}(psh,x, psh,y) = 0.00392699$

$psh,x \text{ (5.4d)} = 0.00392699$
 $Ash = Astir*ns = 78.53982$
No stirups, $ns = 2.00$
 $bk = 400.00$

$psh,y \text{ (5.4d)} = 0.00392699$
 $Ash = Astir*ns = 78.53982$
No stirups, $ns = 2.00$
 $bk = 400.00$

$s = 100.00$
 $f_{ywe} = 555.5556$
 $f_{ce} = 20.00$
From ((5.A5), TBDY), TBDY: $cc = 0.00411734$
 $c = \text{confinement factor} = 1.21173$
 $y1 = 0.0012967$
 $sh1 = 0.0044814$
 $ft1 = 373.4504$
 $fy1 = 311.2087$
 $su1 = 0.00512$
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
 $lo/lou,min = lb/d = 0.30$
 $su1 = 0.4*esu1_nominal \text{ ((5.5), TBDY)} = 0.032$
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 $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs1 = fs = 311.2087$
with $Es1 = Es = 200000.00$
 $y2 = 0.0012967$
 $sh2 = 0.0044814$
 $ft2 = 373.4504$
 $fy2 = 311.2087$
 $su2 = 0.00512$
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 $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs2 = fs = 311.2087$
with $Es2 = Es = 200000.00$
 $yv = 0.0012967$

$shv = 0.0044814$
 $ftv = 373.4504$
 $fyv = 311.2087$
 $suv = 0.00512$
 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 $fsv = fs = 311.2087$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 24.23468$
 $cc (5A.5, TBDY) = 0.00411734$
 $c = confinement\ factor = 1.21173$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.1160777$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.1160777$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.0562801$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs,y2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.2021744$
 $Mu = MRc (4.14) = 1.1045E+008$
 $u = su (4.1) = 1.7976030E-005$

 Calculation of ratio lb/ld

 Inadequate Lap Length with $lb/ld = 0.30$

 Calculation of Shear Strength $Vr = Min(Vr1,Vr2) = 524051.339$

 Calculation of Shear Strength at edge 1, $Vr1 = 524051.339$

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

$VColO = 524051.339$

$knl = 1$ (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)

$M/Vd = 2.00$

$Mu = 4.6307395E-012$

$Vu = 4.2515079E-047$

$d = 0.8*h = 320.00$

$Nu = 5926.932$

$Ag = 160000.00$

From (11.5.4.8), ACI 318-14: $Vs = 223402.144$

$Av = 157079.633$

$fy = 444.4444$

$$s = 100.00$$

Vs is multiplied by Col = 1.00

$$s/d = 0.3125$$

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

f = 0.95, for fully-wrapped sections

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

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

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

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

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

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

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

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

$$E_f = 64828.00$$

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

with $f_u = 0.01$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 380269.701$$

$$bw = 400.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 524051.339$

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

$$V_{ColO} = 524051.339$$

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)

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

$$M/Vd = 2.00$$

$$M_u = 4.6307395E-012$$

$$V_u = 4.2515079E-047$$

$$d = 0.8 * h = 320.00$$

$$N_u = 5926.932$$

$$A_g = 160000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 223402.144$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs is multiplied by Col = 1.00

$$s/d = 0.3125$$

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

f = 0.95, for fully-wrapped sections

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

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

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

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

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

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

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

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

$$E_f = 64828.00$$

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

with $f_u = 0.01$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 380269.701$$

$$bw = 400.00$$

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, $\phi = 0.95$

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

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Section Height, $H = 400.00$

Section Width, $W = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $M = 5.8739332E-010$

Shear Force, $V_2 = -4519.381$

Shear Force, $V_3 = -1.5368441E-013$

Axial Force, $F = -5925.123$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl} = 829.3805$

-Compression: $A_{slc} = 1231.504$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Mean Diameter of Tension Reinforcement, $DbL = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \phi * u = 0.00272023$

$u = y + p = 0.0028634$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.0028634 ((4.29), \text{Biskinis Phd})$

$M_y = 7.7038E+007$

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

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 1.3452E+013$

factor = 0.30

$A_g = 160000.00$

$f_c' = 20.00$

$N = 5925.123$

$E_c * I_g = 4.4841E+013$

Calculation of Yielding Moment M_y

Calculation of ρ_y and M_y according to Annex 7 -

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

$y_{ten} = 4.8497530E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 248.9669$

$d = 357.00$

$y = 0.28100837$

$A = 0.01459862$

$B = 0.00825179$

with $p_t = 0.00580799$

$p_c = 0.00580799$

$p_v = 0.00281599$

$N = 5925.123$

$b = 400.00$

$\rho = 0.12044818$

$y_{comp} = 1.8620192E-005$

with f_c^* (12.3, (ACI 440)) = 21.65599

$f_c = 20.00$

$f_l = 0.93147527$

$b = 400.00$

$h = 400.00$

$A_g = 160000.00$

From (12.9), ACI 440: $k_a = 0.56708553$

$g = p_t + p_c + p_v = 0.01443197$

$r_c = 40.00$

$A_e / A_c = 0.56708553$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 21019.039$

$y = 0.27898785$

$A = 0.0143201$

$B = 0.00808514$

with $E_s = 200000.00$

Calculation of ratio I_b / I_d

Inadequate Lap Length with $I_b / I_d = 0.30$

- Calculation of ρ_p -

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

with:

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

shear control ratio $V_y E / V_{CoI OE} = 0.14050197$

$d = 357.00$

$s = 0.00$

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

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

$b_w = 400.00$

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

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

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

NUD = 5925.123

Ag = 160000.00

f_{cE} = 20.00

f_{ytE} = f_{ylE} = 0.00

pl = Area_Tot_Long_Rein/(b*d) = 0.01443197

b = 400.00

d = 357.00

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

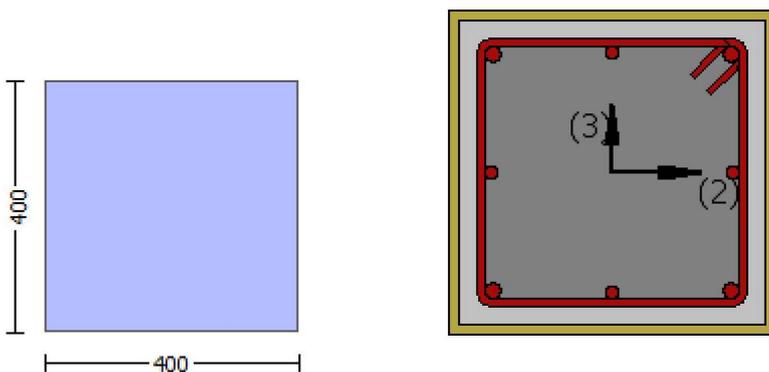
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



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

At local axis: 3

Integration Section: (a)

Section Type: rcrs

Constant Properties

Knowledge Factor, = 0.95

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$

#####

Section Height, $H = 400.00$

Section Width, $W = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $M_a = 5.8739332E-010$

Shear Force, $V_a = -1.5368441E-013$

EDGE -B-

Bending Moment, $M_b = -1.2603819E-010$

Shear Force, $V_b = 1.5368441E-013$

BOTH EDGES

Axial Force, $F = -5925.123$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression: $A_{sl,c} = 1231.504$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

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

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 445406.993$

V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoI} = 468849.466$

$V_{CoI} = 468849.466$

$k_n = 1.00$

$displacement_ductility_demand = 0.00$

NOTE: In expression (10-3) ' $V_s = A_v \phi f_y d/s$ ' is replaced by ' $V_s + \phi V_f$ ' 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)

$M/Vd = 2.00$

$\mu = 5.8739332E-010$
 $V_u = 1.5368441E-013$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 5925.123$
 $A_g = 160000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 201061.93$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.3125$
 V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 357.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 340123.561$
 $b_w = 400.00$

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 $\theta = 1.7026306E-020$
 $y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.0028634$ ((4.29), Biskinis Phd)
 $M_y = 7.7038E+007$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00
 From table 10.5, ASCE 41_17: $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 1.3452E+013$
 $\text{factor} = 0.30$
 $A_g = 160000.00$
 $f_c' = 20.00$
 $N = 5925.123$
 $E_c \cdot I_g = 4.4841E+013$

Calculation of Yielding Moment M_y

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

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 4.8497530E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 248.9669$
 $d = 357.00$
 $y = 0.28100837$
 $A = 0.01459862$
 $B = 0.00825179$
 with $p_t = 0.00580799$
 $p_c = 0.00580799$
 $p_v = 0.00281599$
 $N = 5925.123$
 $b = 400.00$
 $\rho = 0.12044818$
 $y_{\text{comp}} = 1.8620192E-005$

with f_c^* (12.3, (ACI 440)) = 21.65599
 $f_c = 20.00$
 $f_l = 0.93147527$
 $b = 400.00$
 $h = 400.00$
 $A_g = 160000.00$
 From (12.9), ACI 440: $k_a = 0.56708553$
 $g = p_t + p_c + p_v = 0.01443197$
 $r_c = 40.00$
 $A_e/A_c = 0.56708553$
 Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.27898785$
 $A = 0.0143201$
 $B = 0.00808514$
 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: (a)

Calculation No. 4

column C1, Floor 1

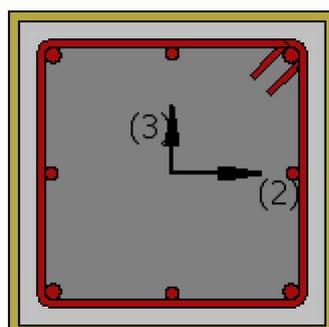
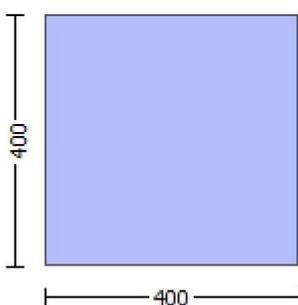
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_u)

Edge: Start

Local Axis: (3)



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

Constant Properties

Knowledge Factor, $\phi = 0.95$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
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, $f_s = 1.25 \cdot f_{sm} = 555.5556$
#####

Section Height, $H = 400.00$
Section Width, $W = 400.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.21173
Element Length, $L = 3000.00$
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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, $N_{Dir} = 1$
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, $V_a = -6.9434686E-031$
EDGE -B-
Shear Force, $V_b = 6.9434686E-031$
BOTH EDGES
Axial Force, $F = -5926.932$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st, \text{ten}} = 829.3805$
-Compression: $A_{sl, \text{com}} = 829.3805$
-Middle: $A_{sl, \text{mid}} = 402.1239$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.14050197$
Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 73630.246$

with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.1045E+008$
 $M_{u1+} = 1.1045E+008$, 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
 $M_{u1-} = 1.1045E+008$, 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
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.1045E+008$
 $M_{u2+} = 1.1045E+008$, 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
 $M_{u2-} = 1.1045E+008$, 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:

$\phi_u = 1.7976030E-005$
 $M_u = 1.1045E+008$

with full section properties:

$b = 400.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00207526$
 $N = 5926.932$
 $f_c = 20.00$
 $\alpha_1(5A.5, \text{TBDY}) = 0.002$
Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.018$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_{cu} = 0.018$
 $\phi_{cu}((5.4c), \text{TBDY}) = \alpha_1 * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.14357935$
where $\phi_{fx} = \alpha_1 * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\phi_{fx} = 0.11712639$
 $\alpha_1 = 0.57333333$
 $b = 400.00$
 $h = 400.00$
From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.00508$
 $bw = 400.00$
effective stress from (A.35), $f_{fe} = 804.2922$

 $\phi_{fy} = 0.11712639$
 $\alpha_1 = 0.57333333$
 $b = 400.00$
 $h = 400.00$
From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.00508$
 $bw = 400.00$
effective stress from (A.35), $f_{fe} = 804.2922$

 $R = 40.00$
Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{f} = 0.015$
 $\alpha_1 \text{ase}((5.4d), \text{TBDY}) = 0.24250288$
 $b_o = 340.00$
 $h_o = 340.00$
 $b_i^2 = 462400.00$
 $\rho_{sh,\min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.00392699$

 $\rho_{sh,x}((5.4d)) = 0.00392699$
 $A_{sh} = A_{stir} * n_s = 78.53982$
No stirups, $n_s = 2.00$
 $b_k = 400.00$

psh,y (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00
d = 327.00
d' = 13.00

fcc (5A.2, TBDY) = 24.23468
cc (5A.5, TBDY) = 0.00411734
c = confinement factor = 1.21173
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1160777
2 = Asl,com/(b*d)*(fs2/fc) = 0.1160777
v = Asl,mid/(b*d)*(fsv/fc) = 0.0562801
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

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

--->
su (4.9) = 0.2021744
Mu = MRc (4.14) = 1.1045E+008
u = su (4.1) = 1.7976030E-005

Calculation of ratio lb/l_d

Inadequate Lap Length with lb/l_d = 0.30

Calculation of Mu1-

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

u = 1.7976030E-005
Mu = 1.1045E+008

with full section properties:

b = 400.00
d = 357.00
d' = 43.00
v = 0.00207526
N = 5926.932
fc = 20.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.018
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.018
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.14357935
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.11712639
af = 0.57333333
b = 400.00
h = 400.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00508
bw = 400.00
effective stress from (A.35), ff,e = 804.2922

fy = 0.11712639
af = 0.57333333
b = 400.00
h = 400.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00508
bw = 400.00
effective stress from (A.35), ff,e = 804.2922

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) = 0.24250288
bo = 340.00

ho = 340.00
bi2 = 462400.00
psh,min = Min(psh,x , psh,y) = 0.00392699

psh,x (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

psh,y (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173
y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
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 = 311.2087

with $E_{sv} = E_s = 200000.00$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.09037478$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09037478$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.04381808$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 24.23468$$

$$c_c (5A.5, TBDY) = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1160777$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1160777$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.2021744$$

$$M_u = M_{Rc} (4.14) = 1.1045E+008$$

$$u = s_u (4.1) = 1.7976030E-005$$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of M_{u2+}

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

$$u = 1.7976030E-005$$

$$M_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

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

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

$$w_e ((5.4c), TBDY) = a_s e^* s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$$

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

$$f_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$f_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

R = 40.00
Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase((5.4d), TBDY) = 0.24250288$
 $bo = 340.00$
 $ho = 340.00$
 $bi_2 = 462400.00$
 $psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00392699$

$psh_{,x}(5.4d) = 0.00392699$
 $Ash = Astir \cdot ns = 78.53982$
No stirrups, $ns = 2.00$
 $bk = 400.00$

$psh_{,y}(5.4d) = 0.00392699$
 $Ash = Astir \cdot ns = 78.53982$
No stirrups, $ns = 2.00$
 $bk = 400.00$

$s = 100.00$
 $fy_{we} = 555.5556$
 $f_{ce} = 20.00$

From $((5.A5), TBDY), TBDY: cc = 0.00411734$
 $c = \text{confinement factor} = 1.21173$

$y_1 = 0.0012967$
 $sh_1 = 0.0044814$
 $ft_1 = 373.4504$
 $fy_1 = 311.2087$
 $su_1 = 0.00512$

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

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

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

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

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

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

with $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0012967$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4504$
 $fy_2 = 311.2087$
 $su_2 = 0.00512$

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

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

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

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

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

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

with $fs_2 = fs = 311.2087$

with $Es_2 = Es = 200000.00$

$y_v = 0.0012967$
 $sh_v = 0.0044814$
 $ft_v = 373.4504$
 $fy_v = 311.2087$
 $suv = 0.00512$

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

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

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

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

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

$$\text{with } f_{sv} = f_s = 311.2087$$

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.09037478$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.09037478$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.04381808$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 24.23468$$

$$c_c (5A.5, TBDY) = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.1160777$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.1160777$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.2021744$$

$$\mu_u = M_{Rc} (4.14) = 1.1045E+008$$

$$u = s_u (4.1) = 1.7976030E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_u -

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

$$u = 1.7976030E-005$$

$$\mu_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

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

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

$$w_e ((5.4c), TBDY) = a_s * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$$

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

$$f_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

fy = 0.11712639
af = 0.57333333
b = 400.00
h = 400.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00508
bw = 400.00
effective stress from (A.35), ff,e = 804.2922

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) = 0.24250288
bo = 340.00
ho = 340.00
bi2 = 462400.00
psh,min = Min(psh,x , psh,y) = 0.00392699

psh,x (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

psh,y (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173
y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 = 311.2087
with Es1 = Es = 200000.00
y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 = 311.2087
with Es2 = Es = 200000.00

$y_v = 0.0012967$
 $sh_v = 0.0044814$
 $ft_v = 373.4504$
 $fy_v = 311.2087$
 $su_v = 0.00512$
 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
 $lo/lo_{u,min} = lb/ld = 0.30$
 $su_v = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fs_v = fsv/1.2$, 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 $fsv = fs = 311.2087$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.09037478$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.09037478$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.04381808$

and confined core properties:

$b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 24.23468$
 $cc (5A.5, TBDY) = 0.00411734$
 $c = \text{confinement factor} = 1.21173$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.1160777$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.1160777$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.0562801$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

$su (4.9) = 0.2021744$

$Mu = MRc (4.14) = 1.1045E+008$

$u = su (4.1) = 1.7976030E-005$

 Calculation of ratio lb/ld

 Inadequate Lap Length with $lb/ld = 0.30$

 Calculation of Shear Strength $V_r = Min(V_{r1}, V_{r2}) = 524051.339$

 Calculation of Shear Strength at edge 1, $V_{r1} = 524051.339$

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

$V_{Col0} = 524051.339$

$knl = 1$ (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 $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$Mu = 1.8671199E-011$

$Vu = 6.9434686E-031$

$d = 0.8 * h = 320.00$

$Nu = 5926.932$

$Ag = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = 223402.144$

$Av = 157079.633$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs is multiplied by Col = 1.00

$$s/d = 0.3125$$

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

f = 0.95, for fully-wrapped sections

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

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

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

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

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

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

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

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

$$E_f = 64828.00$$

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

with $f_u = 0.01$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 380269.701$$

$$b_w = 400.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 524051.339$

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

$$V_{Col0} = 524051.339$$

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)

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

$$M/Vd = 2.00$$

$$\mu_u = 1.8671199E-011$$

$$\nu_u = 6.9434686E-031$$

$$d = 0.8 * h = 320.00$$

$$N_u = 5926.932$$

$$A_g = 160000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 223402.144$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs is multiplied by Col = 1.00

$$s/d = 0.3125$$

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

f = 0.95, for fully-wrapped sections

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

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

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

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

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

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

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

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

$$E_f = 64828.00$$

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

with $f_u = 0.01$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 380269.701$$

$$b_w = 400.00$$

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

At local axis: 3

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

Constant Properties

Knowledge Factor, $\phi = 0.95$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

Section Height, $H = 400.00$
Section Width, $W = 400.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.21173
Element Length, $L = 3000.00$
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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: 2
EDGE -A-
Shear Force, $V_a = 4.2515079E-047$
EDGE -B-
Shear Force, $V_b = -4.2515079E-047$
BOTH EDGES
Axial Force, $F = -5926.932$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{l,ten} = 829.3805$
-Compression: $As_{l,com} = 829.3805$
-Middle: $As_{l,mid} = 402.1239$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.14050197$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 73630.246$
with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.1045E+008$

$M_{u1+} = 1.1045E+008$, 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

$M_{u1-} = 1.1045E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.1045E+008$

$M_{u2+} = 1.1045E+008$, 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

$M_{u2-} = 1.1045E+008$, 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:

$\phi_u = 1.7976030E-005$

$M_u = 1.1045E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00207526$

$N = 5926.932$

$f_c = 20.00$

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

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

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

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

$\omega_e ((5.4c), \text{TBDY}) = \alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.14357935$

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

 $\phi_x = 0.11712639$

$\alpha f = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 804.2922$

$\phi_y = 0.11712639$

$\alpha f = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 804.2922$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$\alpha s_e ((5.4d), \text{TBDY}) = 0.24250288$

$b_o = 340.00$

$h_o = 340.00$

$b_{i2} = 462400.00$

$\rho_{sh,\min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.00392699$

$\rho_{sh,x} (5.4d) = 0.00392699$

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

No stirups, $n_s = 2.00$

bk = 400.00

psh,y (5.4d) = 0.00392699

Ash = Astir*ns = 78.53982

No stirups, ns = 2.00

bk = 400.00

s = 100.00

fywe = 555.5556

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00411734

c = confinement factor = 1.21173

y1 = 0.0012967

sh1 = 0.0044814

ft1 = 373.4504

fy1 = 311.2087

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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00
fcc (5A.2, TBDY) = 24.23468
cc (5A.5, TBDY) = 0.00411734
c = confinement factor = 1.21173
1 = $Asl,ten/(b*d)*(fs1/fc) = 0.1160777$
2 = $Asl,com/(b*d)*(fs2/fc) = 0.1160777$
v = $Asl,mid/(b*d)*(fsv/fc) = 0.0562801$
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

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

--->
su (4.9) = 0.2021744
Mu = MRc (4.14) = 1.1045E+008
u = su (4.1) = 1.7976030E-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 = 1.7976030E-005
Mu = 1.1045E+008

with full section properties:

b = 400.00
d = 357.00
d' = 43.00
v = 0.00207526
N = 5926.932
fc = 20.00
co (5A.5, TBDY) = 0.002
Final value of cu: $cu^* = shear_factor * Max(cu, cc) = 0.018$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $cu = 0.018$
 $we ((5.4c), TBDY) = ase * sh,min*fywe/fce + Min(fx, fy) = 0.14357935$
where $f = af*pf*ffe/fce$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.11712639
af = 0.57333333
b = 400.00
h = 400.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$
bw = 400.00
effective stress from (A.35), $ffe = 804.2922$

fy = 0.11712639
af = 0.57333333
b = 400.00
h = 400.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$
bw = 400.00
effective stress from (A.35), $ffe = 804.2922$

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) = 0.24250288

bo = 340.00
ho = 340.00
bi2 = 462400.00
psh,min = Min(psh,x , psh,y) = 0.00392699

psh,x (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

psh,y (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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/l 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/l d)^ 2/3), from 10.3.5, ASCE41-17.

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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/l b,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/l d)^ 2/3), from 10.3.5, ASCE41-17.

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
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/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 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/l d)^ 2/3), from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 311.2087$
with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.09037478$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09037478$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.04381808$

and confined core properties:

$b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 24.23468$
 $cc (5A.5, TBDY) = 0.00411734$
 $c = \text{confinement factor} = 1.21173$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1160777$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1160777$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0562801$

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

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

--->
 $su (4.9) = 0.2021744$
 $Mu = MRc (4.14) = 1.1045E+008$
 $u = su (4.1) = 1.7976030E-005$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of Mu_{2+}

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

$u = 1.7976030E-005$
 $Mu = 1.1045E+008$

with full section properties:

$b = 400.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00207526$
 $N = 5926.932$
 $f_c = 20.00$
 $co (5A.5, TBDY) = 0.002$

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

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

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

$w_e (5.4c, TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$

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

 $f_x = 0.11712639$
 $a_f = 0.57333333$

$b = 400.00$
 $h = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 804.2922$

$f_y = 0.11712639$
 $a_f = 0.57333333$

$b = 400.00$
 $h = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 804.2922$

R = 40.00

Effective FRP thickness, $t_f = NL*t*\cos(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} ((5.4d), TBDY) = 0.24250288$

$b_o = 340.00$

$h_o = 340.00$

$b_{i2} = 462400.00$

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$

$p_{sh,x} (5.4d) = 0.00392699$

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

No stirrups, $n_s = 2.00$

$b_k = 400.00$

$p_{sh,y} (5.4d) = 0.00392699$

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

No stirrups, $n_s = 2.00$

$b_k = 400.00$

s = 100.00

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00411734$

c = confinement factor = 1.21173

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

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.

with $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0012967$

$sh_2 = 0.0044814$

$ft_2 = 373.4504$

$fy_2 = 311.2087$

$su_2 = 0.00512$

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.

with $fs_2 = fs = 311.2087$

with $Es_2 = Es = 200000.00$

$y_v = 0.0012967$

$sh_v = 0.0044814$

$ft_v = 373.4504$

$fy_v = 311.2087$

$suv = 0.00512$

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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 24.23468

cc (5A.5, TBDY) = 0.00411734

c = confinement factor = 1.21173

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1160777

2 = Asl,com/(b*d)*(fs2/fc) = 0.1160777

v = Asl,mid/(b*d)*(fsv/fc) = 0.0562801

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

su (4.9) = 0.2021744

Mu = MRc (4.14) = 1.1045E+008

u = su (4.1) = 1.7976030E-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 = 1.7976030E-005

Mu = 1.1045E+008

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00207526

N = 5926.932

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.018

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

From (5.4b), TBDY: cu = 0.018

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.14357935

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

fx = 0.11712639

af = 0.57333333

b = 400.00

h = 400.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00508

bw = 400.00

effective stress from (A.35), $f_{f,e} = 804.2922$

$f_y = 0.11712639$
 $a_f = 0.57333333$
 $b = 400.00$
 $h = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.00508$
 $bw = 400.00$
effective stress from (A.35), $f_{f,e} = 804.2922$

$R = 40.00$
Effective FRP thickness, $t_f = NL*t*Cos(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $a_{se} \text{ ((5.4d), TBDY)} = 0.24250288$
 $b_o = 340.00$
 $h_o = 340.00$
 $b_{i2} = 462400.00$
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$

$p_{sh,x} \text{ (5.4d)} = 0.00392699$
 $A_{sh} = A_{stir}*n_s = 78.53982$
No stirups, $n_s = 2.00$
 $b_k = 400.00$

$p_{sh,y} \text{ (5.4d)} = 0.00392699$
 $A_{sh} = A_{stir}*n_s = 78.53982$
No stirups, $n_s = 2.00$
 $b_k = 400.00$

$s = 100.00$
 $f_{ywe} = 555.5556$
 $f_{ce} = 20.00$

From ((5.A.5), TBDY), TBDY: $c_c = 0.00411734$
 $c = \text{confinement factor} = 1.21173$

$y_1 = 0.0012967$
 $sh_1 = 0.0044814$
 $ft_1 = 373.4504$
 $fy_1 = 311.2087$
 $su_1 = 0.00512$

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

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

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

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 $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0012967$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4504$
 $fy_2 = 311.2087$
 $su_2 = 0.00512$

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

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

$su_2 = 0.4*esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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 $fs_2 = fs = 311.2087$

with $E_s = E_s = 200000.00$
 $y_v = 0.0012967$
 $sh_v = 0.0044814$
 $ft_v = 373.4504$
 $fy_v = 311.2087$
 $suv = 0.00512$
 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 $fs_yv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fs_yv = fsv/1.2$, from table 5.1, TBDY.
 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 $fsv = fs = 311.2087$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.09037478$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.09037478$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.04381808$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 24.23468$
 $cc (5A.5, TBDY) = 0.00411734$
 $c = \text{confinement factor} = 1.21173$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.1160777$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.1160777$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.0562801$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.2021744$
 $Mu = MRc (4.14) = 1.1045E+008$
 $u = su (4.1) = 1.7976030E-005$

 Calculation of ratio lb/ld

 Inadequate Lap Length with $lb/ld = 0.30$

 Calculation of Shear Strength $V_r = Min(V_{r1}, V_{r2}) = 524051.339$

Calculation of Shear Strength at edge 1, $V_{r1} = 524051.339$
 $V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 524051.339$
 $knl = 1$ (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)
 $M/Vd = 2.00$
 $Mu = 4.6307395E-012$
 $Vu = 4.2515079E-047$
 $d = 0.8 * h = 320.00$
 $Nu = 5926.932$
 $Ag = 160000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 223402.144$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs is multiplied by Col = 1.00

$$s/d = 0.3125$$

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

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

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

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

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

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

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

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

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

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 380269.701$$

$$b_w = 400.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 524051.339$

$$V_{r2} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = knl * V_{CoI0}$$

$$V_{CoI0} = 524051.339$$

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

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)

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

$$M/Vd = 2.00$$

$$\mu_u = 4.6307395E-012$$

$$\nu_u = 4.2515079E-047$$

$$d = 0.8 * h = 320.00$$

$$N_u = 5926.932$$

$$A_g = 160000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 223402.144$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs is multiplied by Col = 1.00

$$s/d = 0.3125$$

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

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

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

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

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

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

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

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

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

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 380269.701$$

$$b_w = 400.00$$

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

At local axis: 2

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

At local axis: 3

Integration Section: (a)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 0.95$

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

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Section Height, $H = 400.00$

Section Width, $W = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $M = -1.3563E+007$

Shear Force, $V_2 = -4519.381$

Shear Force, $V_3 = -1.5368441E-013$

Axial Force, $F = -5925.123$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 829.3805$

-Compression: $A_{sc} = 1231.504$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Mean Diameter of Tension Reinforcement, $D_{bL} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \gamma \cdot u = 0.00544247$

$u = \gamma \cdot u = 0.00572891$

- Calculation of γ -

$\gamma = (M_y \cdot L_s / 3) / E_{eff} = 0.00572891$ ((4.29), Biskinis Phd))

$M_y = 7.7038E+007$
 $L_s = M/V$ (with $L_s > 0.1*L$ and $L_s < 2*L$) = 3001.112
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.3452E+013$
factor = 0.30
Ag = 160000.00
fc' = 20.00
N = 5925.123
 $E_c * I_g = 4.4841E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.8497530E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 248.9669$
d = 357.00
y = 0.28100837
A = 0.01459862
B = 0.00825179
with pt = 0.00580799
pc = 0.00580799
pv = 0.00281599
N = 5925.123
b = 400.00
" = 0.12044818
 $y_{comp} = 1.8620192E-005$
with fc' (12.3, (ACI 440)) = 21.65599
fc = 20.00
fl = 0.93147527
b = 400.00
h = 400.00
Ag = 160000.00
From (12.9), ACI 440: $k_a = 0.56708553$
g = pt + pc + pv = 0.01443197
rc = 40.00
 $A_e / A_c = 0.56708553$
Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
fu = 0.01
Ef = 64828.00
Ec = 21019.039
y = 0.27898785
A = 0.0143201
B = 0.00808514
with Es = 200000.00

Calculation of ratio I_b / I_d

Inadequate Lap Length with $I_b / I_d = 0.30$

- Calculation of p -

From table 10-8: $p = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $I_b / I_d >= 1$
shear control ratio $V_y E / C_o I_o E = 0.14050197$
d = 357.00
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 = 400.00

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.

$$N_{UD} = 5925.123$$

$$A_g = 160000.00$$

$$f_{cE} = 20.00$$

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

$$\rho_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.01443197$$

$$b = 400.00$$

$$d = 357.00$$

$$f_{cE} = 20.00$$

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

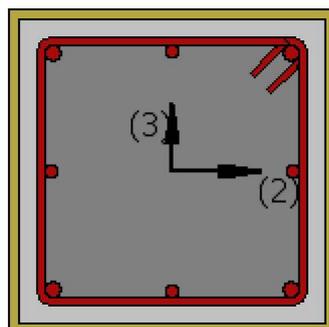
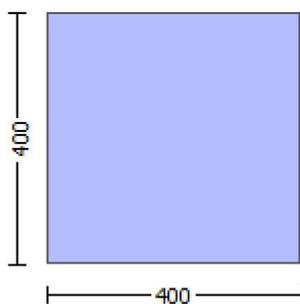
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (2)



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

At local axis: 2

Integration Section: (b)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 0.95$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$

#####

Section Height, $H = 400.00$

Section Width, $W = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $M_a = -1.3563E+007$

Shear Force, $V_a = -4519.381$

EDGE -B-

Bending Moment, $M_b = 0.1333213$

Shear Force, $V_b = 4519.381$

BOTH EDGES

Axial Force, $F = -5925.123$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

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

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

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

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 445406.993$

V_n ((10.3), ASCE 41-17) = $k_n \phi V_{Col} = 468849.466$

$V_{Col} = 468849.466$

$k_n = 1.00$

$displacement_ductility_demand = 0.26406097$

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)

$M/Vd = 2.00$

$\mu_u = 0.1333213$

$V_u = 4519.381$

$d = 0.8 \cdot h = 320.00$

$N_u = 5925.123$

$A_g = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = 201061.93$

$A_v = 157079.633$

$f_y = 400.00$

$s = 100.00$

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

$s/d = 0.3125$

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

$f = 0.95$, for fully-wrapped sections

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

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

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

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

orientation 1: $\theta = 45^\circ$ and $\theta = -45^\circ$

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

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

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 340123.561$

$b_w = 400.00$

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 $\theta = 0.00015122$

$y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00057268$ ((4.29), Biskinis Phd)

$M_y = 7.7038 \text{E} + 007$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00

From table 10.5, ASCE 41_17: $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 1.3452 \text{E} + 013$

factor = 0.30

$A_g = 160000.00$

$f_c' = 20.00$

$N = 5925.123$

$E_c \cdot I_g = 4.4841 \text{E} + 013$

Calculation of Yielding Moment M_y

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

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

$y_{\text{ten}} = 4.8497530 \text{E} - 006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 248.9669$

$d = 357.00$

$y = 0.28100837$

$A = 0.01459862$

$B = 0.00825179$

with $p_t = 0.00580799$

$p_c = 0.00580799$

$p_v = 0.00281599$

$N = 5925.123$

$b = 400.00$

" = 0.12044818
y_comp = 1.8620192E-005
with f_c^* (12.3, (ACI 440)) = 21.65599
f_c = 20.00
f_l = 0.93147527
b = 400.00
h = 400.00
A_g = 160000.00
From (12.9), ACI 440: $k_a = 0.56708553$
g = $p_t + p_c + p_v = 0.01443197$
r_c = 40.00
A_e/A_c = 0.56708553
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 = 0.27898785
A = 0.0143201
B = 0.00808514
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: 2

Integration Section: (b)

Calculation No. 6

column C1, Floor 1

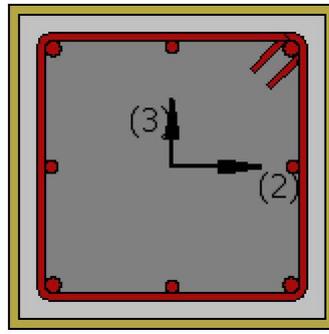
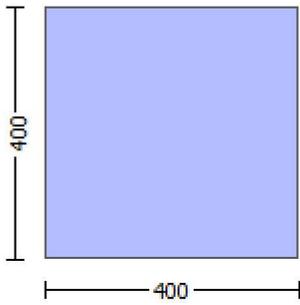
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: End

Local Axis: (2)



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

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

Constant Properties

Knowledge Factor, $\gamma = 0.95$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
 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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

 Section Height, $H = 400.00$
 Section Width, $W = 400.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.21173
 Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 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, $V_a = -6.9434686E-031$
 EDGE -B-
 Shear Force, $V_b = 6.9434686E-031$
 BOTH EDGES
 Axial Force, $F = -5926.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: Aslt = 0.00

-Compression: Aslc = 2060.885

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: Asl,ten = 829.3805

-Compression: Asl,com = 829.3805

-Middle: Asl,mid = 402.1239

Calculation of Shear Capacity ratio , $V_e/V_r = 0.14050197$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 73630.246$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.1045E+008$

$M_{u1+} = 1.1045E+008$, 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

$M_{u1-} = 1.1045E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.1045E+008$

$M_{u2+} = 1.1045E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 1.1045E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of M_{u1+}

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

$\phi_u = 1.7976030E-005$

$M_u = 1.1045E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00207526$

$N = 5926.932$

$f_c = 20.00$

ϕ_c (5A.5, TBDY) = 0.002

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

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

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

$\phi_{u,e}$ ((5.4c), TBDY) = $\phi_{u,e} = \text{ase} * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.14357935$

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

$\phi_x = 0.11712639$

$\text{af} = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 804.2922$

$\phi_y = 0.11712639$

$\text{af} = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 804.2922$

$R = 40.00$

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) = 0.24250288
bo = 340.00
ho = 340.00
bi2 = 462400.00
psh,min = Min(psh,x , psh,y) = 0.00392699

psh,x (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

psh,y (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173
y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 = 311.2087
with Es1 = Es = 200000.00
y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 = 311.2087
with Es2 = Es = 200000.00
yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
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 $e_{suv_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

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

with $f_{sv} = f_s = 311.2087$

with $E_{sv} = E_s = 200000.00$

1 = $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.09037478$

2 = $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09037478$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.04381808$

and confined core properties:

$b = 340.00$

$d = 327.00$

$d' = 13.00$

f_{cc} (5A.2, TBDY) = 24.23468

cc (5A.5, TBDY) = 0.00411734

c = confinement factor = 1.21173

1 = $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.1160777$

2 = $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.1160777$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.0562801$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.2021744

$Mu = MRc$ (4.14) = 1.1045E+008

$u = su$ (4.1) = 1.7976030E-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:

$u = 1.7976030E-005$

$Mu = 1.1045E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00207526$

$N = 5926.932$

$f_c = 20.00$

co (5A.5, TBDY) = 0.002

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

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

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

w_e ((5.4c), TBDY) = $ase \cdot sh_{,min} \cdot fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.14357935$

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

 $fx = 0.11712639$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $pf = 2t_f/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $ff_{,e} = 804.2922$

$fy = 0.11712639$

$af = 0.57333333$

b = 400.00
h = 400.00
From EC8 A 4.4.3(6), $pf = 2tf/bw = 0.00508$
bw = 400.00
effective stress from (A.35), $ff,e = 804.2922$

R = 40.00
Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase ((5.4d), TBDY) = 0.24250288$
bo = 340.00
ho = 340.00
bi2 = 462400.00
 $psh,min = Min(psh,x , psh,y) = 0.00392699$

$psh,x (5.4d) = 0.00392699$
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

$psh,y (5.4d) = 0.00392699$
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

s = 100.00
 $fywe = 555.5556$
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173
 $y1 = 0.0012967$
 $sh1 = 0.0044814$
 $ft1 = 373.4504$
 $fy1 = 311.2087$
 $su1 = 0.00512$
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 $fs1 = fs = 311.2087$
with $Es1 = Es = 200000.00$
 $y2 = 0.0012967$
 $sh2 = 0.0044814$
 $ft2 = 373.4504$
 $fy2 = 311.2087$
 $su2 = 0.00512$
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 $fs2 = fs = 311.2087$
with $Es2 = Es = 200000.00$
 $yv = 0.0012967$
 $shv = 0.0044814$
 $ftv = 373.4504$

$$f_{yv} = 311.2087$$

$$s_{uv} = 0.00512$$

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 $f_{sv} = f_{sv}/1.2$, 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.

$$\text{with } f_{sv} = f_s = 311.2087$$

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.09037478$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09037478$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.04381808$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 24.23468$$

$$c_c (5A.5, TBDY) = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1160777$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1160777$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.2021744$$

$$\mu_u = M_{Rc} (4.14) = 1.1045E+008$$

$$u = s_u (4.1) = 1.7976030E-005$$

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:

$$u = 1.7976030E-005$$

$$\mu_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

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

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

$$w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$$

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

$$f_x = 0.11712639$$

$$a_f = 0.57333333$$

b = 400.00
h = 400.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$
bw = 400.00
effective stress from (A.35), $ff,e = 804.2922$

fy = 0.11712639
af = 0.57333333
b = 400.00
h = 400.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$
bw = 400.00
effective stress from (A.35), $ff,e = 804.2922$

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) = 0.24250288
bo = 340.00
ho = 340.00
bi2 = 462400.00
psh,min = Min(psh,x , psh,y) = 0.00392699

psh,x (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

psh,y (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173
y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 $fs1 = fs = 311.2087$

with $Es1 = Es = 200000.00$

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 , $sh_{2,ft2,fy2}$, it is considered characteristic value $fs_{y2} = fs_2/1.2$, from table 5.1, TBDY.

y_1 , $sh_{1,ft1,fy1}$, are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 311.2087$

with $Es_2 = Es = 200000.00$

$y_v = 0.0012967$

$sh_v = 0.0044814$

$ft_v = 373.4504$

$fy_v = 311.2087$

$s_{uv} = 0.00512$

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

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

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

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

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

For calculation of $es_{uv_nominal}$ and y_v , sh_v, ft_v, fy_v , it is considered characteristic value $fs_{yv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1 , $sh_{1,ft1,fy1}$, are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = fs = 311.2087$

with $Es_v = Es = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.09037478$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09037478$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.04381808$

and confined core properties:

$b = 340.00$

$d = 327.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 24.23468$

$cc (5A.5, TBDY) = 0.00411734$

$c = \text{confinement factor} = 1.21173$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.1160777$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.1160777$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.0562801$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$s_u (4.9) = 0.2021744$

$\mu_u = MR_c (4.14) = 1.1045E+008$

$u = s_u (4.1) = 1.7976030E-005$

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:

$u = 1.7976030E-005$

$\mu_u = 1.1045E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00207526$

$N = 5926.932$

$f_c = 20.00$

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

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

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

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

w_e ((5.4c), TBDY) = $ase * sh_{min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$

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

 $f_x = 0.11712639$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $f_{f,e} = 804.2922$

 $f_y = 0.11712639$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $f_{f,e} = 804.2922$

 $R = 40.00$

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) = 0.24250288

$bo = 340.00$

$ho = 340.00$

$bi^2 = 462400.00$

$psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00392699$

 $psh_{,x}$ (5.4d) = 0.00392699

$Ash = Astir * ns = 78.53982$

No stirrups, $ns = 2.00$

$bk = 400.00$

 $psh_{,y}$ (5.4d) = 0.00392699

$Ash = Astir * ns = 78.53982$

No stirrups, $ns = 2.00$

$bk = 400.00$

 $s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00411734$

$c = \text{confinement factor} = 1.21173$

$y1 = 0.0012967$

$sh1 = 0.0044814$

$ft1 = 373.4504$

$fy1 = 311.2087$

$su1 = 0.00512$

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

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

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

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

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

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

with $fs1 = fs = 311.2087$

with $Es1 = Es = 200000.00$

$y2 = 0.0012967$

$sh2 = 0.0044814$

$ft2 = 373.4504$

$$f_y2 = 311.2087$$

$$s_u2 = 0.00512$$

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

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

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

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

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

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

$$\text{with } f_{s2} = f_s = 311.2087$$

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

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$f_{y_v} = 311.2087$$

$$s_{u_v} = 0.00512$$

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

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

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

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

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

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

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

$$\text{with } f_{s_v} = f_s = 311.2087$$

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

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.09037478$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.09037478$$

$$v = A_{s1,mid}/(b*d) * (f_{s_v}/f_c) = 0.04381808$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 24.23468$$

$$cc (5A.5, TBDY) = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.1160777$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.1160777$$

$$v = A_{s1,mid}/(b*d) * (f_{s_v}/f_c) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.2021744$$

$$\mu = M_{Rc} (4.14) = 1.1045E+008$$

$$u = s_u (4.1) = 1.7976030E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 524051.339$

Calculation of Shear Strength at edge 1, $V_{r1} = 524051.339$

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

$$V_{CoIo} = 524051.339$$

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

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).

$\lambda = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 1.8671199E-011$
 $V_u = 6.9434686E-031$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 5926.932$
 $A_g = 160000.00$
From (11.5.4.8), ACI 318-14: $V_s = 223402.144$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_s is multiplied by $\lambda = 1.00$
 $s/d = 0.3125$
 V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta = 45^\circ + 90^\circ = 135^\circ$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, 1)|)$, with:
total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 357.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_{e1} = 0.004$, from (11.6a), ACI 440
with $f_{u1} = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 380269.701$
 $b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 524051.339$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n \lambda \cdot V_{Col0}$
 $V_{Col0} = 524051.339$
 $k_n = 1$ (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)
 $M/Vd = 2.00$
 $\mu_u = 1.8671199E-011$
 $V_u = 6.9434686E-031$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 5926.932$
 $A_g = 160000.00$
From (11.5.4.8), ACI 318-14: $V_s = 223402.144$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_s is multiplied by $\lambda = 1.00$
 $s/d = 0.3125$
 V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta = 45^\circ + 90^\circ = 135^\circ$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, 1)|)$, with:

total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 357.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 380269.701$
 $b_w = 400.00$

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

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

Constant Properties

Knowledge Factor, $\gamma = 0.95$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

Section Height, $H = 400.00$
Section Width, $W = 400.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.21173
Element Length, $L = 3000.00$
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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, $V_a = 4.2515079E-047$
EDGE -B-
Shear Force, $V_b = -4.2515079E-047$
BOTH EDGES

Axial Force, $F = -5926.932$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{,ten} = 829.3805$
-Compression: $As_{,com} = 829.3805$
-Middle: $As_{,mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.14050197$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 73630.246$
with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.1045E+008$
 $Mu_{1+} = 1.1045E+008$, 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
 $Mu_{1-} = 1.1045E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.1045E+008$
 $Mu_{2+} = 1.1045E+008$, 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
 $Mu_{2-} = 1.1045E+008$, 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 Mu_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 1.7976030E-005$
 $M_u = 1.1045E+008$

with full section properties:

$b = 400.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00207526$
 $N = 5926.932$

$f_c = 20.00$
 $\omega (5A.5, TBDY) = 0.002$

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

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

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

where $\phi_u = \phi_u^* * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.14357935$

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

 $\phi_x = 0.11712639$

$\phi_x^* = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 804.2922$

 $\phi_y = 0.11712639$

$\phi_y^* = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 804.2922$

 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase((5.4d), TBDY) = 0.24250288$

$b_o = 340.00$

$h_o = 340.00$

$bi2 = 462400.00$

$psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00392699$

$psh_{,x}(5.4d) = 0.00392699$

$Ash = Astir*ns = 78.53982$

No stirups, $ns = 2.00$

$b_k = 400.00$

$psh_{,y}(5.4d) = 0.00392699$

$Ash = Astir*ns = 78.53982$

No stirups, $ns = 2.00$

$b_k = 400.00$

$s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A.5), TBDY), TBDY: $cc = 0.00411734$

$c = \text{confinement factor} = 1.21173$

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

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

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

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

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

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

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

with $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0012967$

$sh_2 = 0.0044814$

$ft_2 = 373.4504$

$fy_2 = 311.2087$

$su_2 = 0.00512$

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

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

$su_2 = 0.4*esu2_{nominal}((5.5), TBDY) = 0.032$

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

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

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

with $fs_2 = fs = 311.2087$

with $Es_2 = Es = 200000.00$

$y_v = 0.0012967$

$sh_v = 0.0044814$

$ft_v = 373.4504$

$fy_v = 311.2087$

$suv = 0.00512$

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 $fsv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 311.2087$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.09037478$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.09037478$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.04381808$

and confined core properties:

$b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 fcc (5A.2, TBDY) = 24.23468
 cc (5A.5, TBDY) = 0.00411734
 $c =$ confinement factor = 1.21173
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.1160777$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.1160777$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.0562801$

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

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

--->
 su (4.9) = 0.2021744
 $Mu = MRc$ (4.14) = 1.1045E+008
 $u = su$ (4.1) = 1.7976030E-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:

$u = 1.7976030E-005$
 $Mu = 1.1045E+008$

with full section properties:

$b = 400.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00207526$
 $N = 5926.932$
 $fc = 20.00$
 co (5A.5, TBDY) = 0.002

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

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

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

we ((5.4c), TBDY) = $ase * sh, min * fywe / fce + Min(fx, fy) = 0.14357935$

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

$fx = 0.11712639$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A4.4.3(6), $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $ffe = 804.2922$

$fy = 0.11712639$

af = 0.57333333
b = 400.00
h = 400.00
From EC8 A.4.4.3(6), pf = $2t_f/bw = 0.00508$
bw = 400.00
effective stress from (A.35), ff,e = 804.2922

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) = 0.24250288
bo = 340.00
ho = 340.00
bi2 = 462400.00
psh,min = $\text{Min}(psh,x, psh,y) = 0.00392699$

psh,x (5.4d) = 0.00392699
Ash = $\text{Astir}*ns = 78.53982$
No stirups, ns = 2.00
bk = 400.00

psh,y (5.4d) = 0.00392699
Ash = $\text{Astir}*ns = 78.53982$
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173
y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 = 311.2087
with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 = 311.2087
with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814

$$ftv = 373.4504$$

$$fyv = 311.2087$$

$$suv = 0.00512$$

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.

$$\text{with } fsv = fs = 311.2087$$

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

$$1 = Asl_{ten}/(b*d)*(fs1/fc) = 0.09037478$$

$$2 = Asl_{com}/(b*d)*(fs2/fc) = 0.09037478$$

$$v = Asl_{mid}/(b*d)*(fsv/fc) = 0.04381808$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 24.23468$$

$$cc (5A.5, TBDY) = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = Asl_{ten}/(b*d)*(fs1/fc) = 0.1160777$$

$$2 = Asl_{com}/(b*d)*(fs2/fc) = 0.1160777$$

$$v = Asl_{mid}/(b*d)*(fsv/fc) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

$$su (4.9) = 0.2021744$$

$$Mu = MRc (4.14) = 1.1045E+008$$

$$u = su (4.1) = 1.7976030E-005$$

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:

$$u = 1.7976030E-005$$

$$Mu = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$fc = 20.00$$

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

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

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

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

$$we ((5.4c), TBDY) = ase * sh_{min} * fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.14357935$$

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

$$fx = 0.11712639$$

af = 0.57333333
b = 400.00
h = 400.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$
bw = 400.00
effective stress from (A.35), $ff,e = 804.2922$

fy = 0.11712639
af = 0.57333333
b = 400.00
h = 400.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$
bw = 400.00
effective stress from (A.35), $ff,e = 804.2922$

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) = 0.24250288
bo = 340.00
ho = 340.00
bi2 = 462400.00
psh,min = Min(psh,x , psh,y) = 0.00392699

psh,x (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

psh,y (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 $fs1 = fs = 311.2087$

with $Es1 = Es = 200000.00$

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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: $es_{u2_nominal} = 0.08$,
For calculation of $es_{u2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fs_{y2} = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs_2 = fs = 311.2087$
with $Es_2 = Es = 200000.00$

$y_v = 0.0012967$
 $sh_v = 0.0044814$
 $ft_v = 373.4504$
 $fy_v = 311.2087$
 $s_{uv} = 0.00512$

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

$lo/lo_{u,min} = lb/d = 0.30$
 $s_{uv} = 0.4 \cdot es_{uv_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,
considering characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY
For calculation of $es_{uv_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs_v = fs = 311.2087$
with $Es_v = Es = 200000.00$

$1 = As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.09037478$
 $2 = As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.09037478$
 $v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.04381808$

and confined core properties:

$b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 24.23468$
 $cc (5A.5, TBDY) = 0.00411734$
 $c = \text{confinement factor} = 1.21173$
 $1 = As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.1160777$
 $2 = As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.1160777$
 $v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.0562801$

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

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

--->
 $s_u (4.9) = 0.2021744$
 $\mu_u = MR_c (4.14) = 1.1045E+008$
 $u = s_u (4.1) = 1.7976030E-005$

Calculation of ratio lb/d

Inadequate Lap Length with $lb/d = 0.30$

Calculation of μ_{u2} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 1.7976030E-005$
 $\mu_u = 1.1045E+008$

with full section properties:

$b = 400.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00207526$
 $N = 5926.932$
 $f_c = 20.00$

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

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

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

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

$$\text{we ((5.4c), TBDY)} = a_{se} * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$$

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

$$f_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$f_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$$

$$p_{sh,x} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$ft_1 = 373.4504$$

$$fy_1 = 311.2087$$

$$su_1 = 0.00512$$

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

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

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

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

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.

$$\text{with } fs_1 = fs = 311.2087$$

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

$$y_2 = 0.0012967$$

$$sh_2 = 0.0044814$$

$$ft2 = 373.4504$$

$$fy2 = 311.2087$$

$$su2 = 0.00512$$

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.

$$\text{with } fs2 = fs = 311.2087$$

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

$$yv = 0.0012967$$

$$shv = 0.0044814$$

$$ftv = 373.4504$$

$$fyv = 311.2087$$

$$suv = 0.00512$$

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.

$$\text{with } fsv = fs = 311.2087$$

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 24.23468$$

$$cc (5A.5, TBDY) = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.1160777$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.1160777$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

$$su (4.9) = 0.2021744$$

$$Mu = MRc (4.14) = 1.1045E+008$$

$$u = su (4.1) = 1.7976030E-005$$

Calculation of ratio lb/ld

Inadequate Lap Length with lb/ld = 0.30

Calculation of Shear Strength $Vr = \text{Min}(Vr1, Vr2) = 524051.339$

Calculation of Shear Strength at edge 1, $Vr1 = 524051.339$

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

$$VColO = 524051.339$$

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

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).

$\lambda = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 4.6307395E-012$
 $V_u = 4.2515079E-047$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 5926.932$
 $A_g = 160000.00$
From (11.5.4.8), ACI 318-14: $V_s = 223402.144$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.3125$
 V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta = 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|)$, with:
total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 357.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_{e1} = 0.004$, from (11.6a), ACI 440
with $f_{u1} = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 380269.701$
 $b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 524051.339$
 $V_{r2} = V_{\text{Col}}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{\text{Col}0}$
 $V_{\text{Col}0} = 524051.339$
 $k_{nl} = 1$ (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)
 $M/Vd = 2.00$
 $\mu_u = 4.6307395E-012$
 $V_u = 4.2515079E-047$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 5926.932$
 $A_g = 160000.00$
From (11.5.4.8), ACI 318-14: $V_s = 223402.144$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.3125$
 V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta = 90^\circ = 90.00$

Vf = Min(|Vf(45, 1)|, |Vf(-45,a1)|), with:
total thickness per orientation, tf1 = NL*t/NoDir = 1.016
dfv = d (figure 11.2, ACI 440) = 357.00
ffe ((11-5), ACI 440) = 259.312
Ef = 64828.00
fe = 0.004, from (11.6a), ACI 440
with fu = 0.01
From (11-11), ACI 440: Vs + Vf <= 380269.701
bw = 400.00

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, = 0.95
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Primary Member: Concrete Strength, fc = fcm = 20.00
Existing material of Primary Member: Steel Strength, fs = fsm = 444.4444
Concrete Elasticity, Ec = 21019.039
Steel Elasticity, Es = 200000.00
Section Height, H = 400.00
Section Width, W = 400.00
Cover Thickness, c = 25.00
Element Length, L = 3000.00
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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 = -1.2603819E-010
Shear Force, V2 = 4519.381
Shear Force, V3 = 1.5368441E-013
Axial Force, F = -5925.123
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 2060.885
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 829.3805
-Compression: Asl,com = 829.3805

-Middle: $Asl_{mid} = 402.1239$

Mean Diameter of Tension Reinforcement, $DbL = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{R} = u = 0.00272023$
 $u = y + p = 0.0028634$

- Calculation of y -

$y = (My * Ls / 3) / E_{eff} = 0.0028634$ ((4.29), Biskinis Phd))
 $My = 7.7038E+007$
 $Ls = M/V$ (with $Ls > 0.1 * L$ and $Ls < 2 * L$) = 1500.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.3452E+013$
factor = 0.30
 $Ag = 160000.00$
 $fc' = 20.00$
 $N = 5925.123$
 $E_c * I_g = 4.4841E+013$

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.8497530E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 248.9669$
 $d = 357.00$
 $y = 0.28100837$
 $A = 0.01459862$
 $B = 0.00825179$
with $pt = 0.00580799$
 $pc = 0.00580799$
 $pv = 0.00281599$
 $N = 5925.123$
 $b = 400.00$
 $" = 0.12044818$
 $y_{comp} = 1.8620192E-005$
with $fc' (12.3, (ACI 440)) = 21.65599$
 $fc = 20.00$
 $fl = 0.93147527$
 $b = 400.00$
 $h = 400.00$
 $Ag = 160000.00$
From (12.9), ACI 440: $ka = 0.56708553$
 $g = pt + pc + pv = 0.01443197$
 $rc = 40.00$
 $Ae / Ac = 0.56708553$
Effective FRP thickness, $t_f = NL * t * \text{Cos}(b1) = 1.016$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $fu = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.27898785$
 $A = 0.0143201$
 $B = 0.00808514$
with $Es = 200000.00$

Calculation of ratio I_b / I_d

Inadequate Lap Length with $I_b / I_d = 0.30$

- 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 $V_{yE}/V_{CoIE} = 0.14050197$

$d = 357.00$

$s = 0.00$

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

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

$b_w = 400.00$

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.

$N_{UD} = 5925.123$

$A_g = 160000.00$

$f_{cE} = 20.00$

$f_{tE} = f_{yIE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein}/(b*d) = 0.01443197$

$b = 400.00$

$d = 357.00$

$f_{cE} = 20.00$

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

At local axis: 2

Integration Section: (b)

Calculation No. 7

column C1, Floor 1

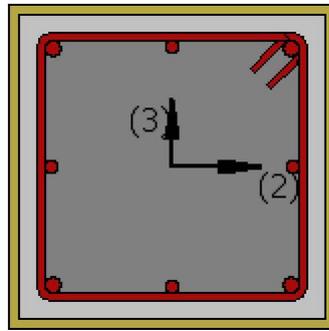
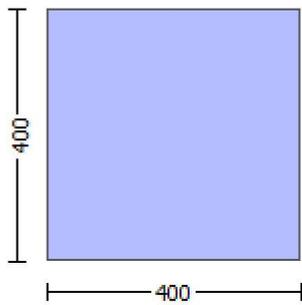
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (3)



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

At local axis: 3

Integration Section: (b)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 0.95$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$

#####

Section Height, $H = 400.00$

Section Width, $W = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $M_a = 5.8739332E-010$

Shear Force, $V_a = -1.5368441E-013$

EDGE -B-

Bending Moment, $M_b = -1.2603819E-010$

Shear Force, $V_b = 1.5368441E-013$
 BOTH EDGES
 Axial Force, $F = -5925.123$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 0.00$
 -Compression: $As_c = 2060.885$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{t,ten} = 829.3805$
 -Compression: $As_{c,com} = 829.3805$
 -Middle: $As_{mid} = 402.1239$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 445406.993$
 V_n ((10.3), ASCE 41-17) = $k_n \phi V_{Co} = 468849.466$
 $V_{Co} = 468849.466$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.00$

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

= 1 (normal-weight concrete)
 $f'_c = 16.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 1.2603819E-010$
 $V_u = 1.5368441E-013$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 5925.123$
 $A_g = 160000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 201061.93$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$

V_s is multiplied by $\phi_{col} = 1.00$
 $s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $\phi_f = 0.95$, for fully-wrapped sections

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

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

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

orientation 1: $\theta_1 = 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

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

ϕ_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

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

with $\phi_{fu} = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 340123.561$

$b_w = 400.00$

$displacement_ductility_demand$ is calculated as δ / y

- Calculation of δ / y for END B -
 for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 9.0140030E-021$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.0028634$ ((4.29), Biskinis Phd))

$M_y = 7.7038E+007$

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

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 1.3452E+013$

factor = 0.30

$A_g = 160000.00$

$f_c' = 20.00$

$N = 5925.123$

$E_c * I_g = 4.4841E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$y_{ten} = 4.8497530E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 248.9669$

$d = 357.00$

$y = 0.28100837$

$A = 0.01459862$

$B = 0.00825179$

with $pt = 0.00580799$

$pc = 0.00580799$

$pv = 0.00281599$

$N = 5925.123$

$b = 400.00$

" = 0.12044818

$y_{comp} = 1.8620192E-005$

with $f_c' (12.3, (ACI 440)) = 21.65599$

$f_c = 20.00$

$fl = 0.93147527$

$b = 400.00$

$h = 400.00$

$A_g = 160000.00$

From (12.9), ACI 440: $k_a = 0.56708553$

$g = pt + pc + pv = 0.01443197$

$rc = 40.00$

$A_e / A_c = 0.56708553$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 21019.039$

$y = 0.27898785$

$A = 0.0143201$

$B = 0.00808514$

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: (b)

Calculation No. 8

column C1, Floor 1

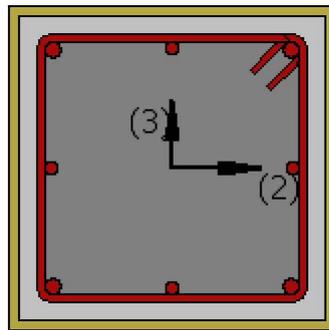
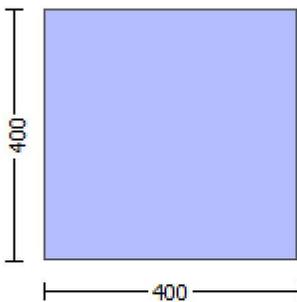
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: End

Local Axis: (3)



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

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 0.95$

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

Section Height, $H = 400.00$

Section Width, $W = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.21173

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $V_a = -6.9434686E-031$

EDGE -B-

Shear Force, $V_b = 6.9434686E-031$

BOTH EDGES

Axial Force, $F = -5926.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Calculation of Shear Capacity ratio, $V_e/V_r = 0.14050197$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 73630.246$

with
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.1045E+008$
 $Mu_{1+} = 1.1045E+008$, 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
 $Mu_{1-} = 1.1045E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.1045E+008$
 $Mu_{2+} = 1.1045E+008$, 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
 $Mu_{2-} = 1.1045E+008$, 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:

$\phi_u = 1.7976030E-005$

$Mu = 1.1045E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00207526$

$N = 5926.932$

$f_c = 20.00$

ϕ_c (5A.5, TBDY) = 0.002

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

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

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

ϕ_u ((5.4c), TBDY) = $\phi_u^* * \text{sh_min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.14357935$

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

$$f_x = 0.11712639$$

$$af = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$f_y = 0.11712639$$

$$af = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00392699$$

$$psh_{,x} \text{ (5.4d)} = 0.00392699$$

$$Ash = Astir \cdot ns = 78.53982$$

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

$$bk = 400.00$$

$$psh_{,y} \text{ (5.4d)} = 0.00392699$$

$$Ash = Astir \cdot ns = 78.53982$$

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

$$bk = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$ft_1 = 373.4504$$

$$fy_1 = 311.2087$$

$$su_1 = 0.00512$$

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

$$l_o/l_{o,min} = lb/ld = 0.30$$

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

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

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

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

$$\text{with } fs_1 = fs = 311.2087$$

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

$$y_2 = 0.0012967$$

$$sh_2 = 0.0044814$$

$$ft_2 = 373.4504$$

$$fy_2 = 311.2087$$

$$su_2 = 0.00512$$

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

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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 24.23468

cc (5A.5, TBDY) = 0.00411734

c = confinement factor = 1.21173

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1160777

2 = Asl,com/(b*d)*(fs2/fc) = 0.1160777

v = Asl,mid/(b*d)*(fsv/fc) = 0.0562801

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.2021744

Mu = MRc (4.14) = 1.1045E+008

u = su (4.1) = 1.7976030E-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 = 1.7976030E-005

Mu = 1.1045E+008

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

$$v = 0.00207526$$

$$N = 5926.932$$

$$fc = 20.00$$

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

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

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

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

$$we \text{ ((5.4c), TBDY)} = ase * sh_{min} * fy_{we} / fce + \text{Min}(fx, fy) = 0.14357935$$

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

$$fx = 0.11712639$$

$$af = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ff,e = 804.2922$$

$$fy = 0.11712639$$

$$af = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ff,e = 804.2922$$

$$R = 40.00$$

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

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = 0.24250288$$

$$bo = 340.00$$

$$ho = 340.00$$

$$bi2 = 462400.00$$

$$psh_{min} = \text{Min}(psh,x, psh,y) = 0.00392699$$

$$psh,x \text{ (5.4d)} = 0.00392699$$

$$Ash = Astir * ns = 78.53982$$

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

$$bk = 400.00$$

$$psh,y \text{ (5.4d)} = 0.00392699$$

$$Ash = Astir * ns = 78.53982$$

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

$$bk = 400.00$$

$$s = 100.00$$

$$fy_{we} = 555.5556$$

$$fce = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$y1 = 0.0012967$$

$$sh1 = 0.0044814$$

$$ft1 = 373.4504$$

$$fy1 = 311.2087$$

$$su1 = 0.00512$$

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.

$$\text{with } fs1 = fs = 311.2087$$

with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0012967$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4504$
 $fy_2 = 311.2087$
 $su_2 = 0.00512$
 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 $fs_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 311.2087$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0012967$
 $sh_v = 0.0044814$
 $ft_v = 373.4504$
 $fy_v = 311.2087$
 $suv = 0.00512$
 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 $fs_v = fs_v/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fs_v = fs_v/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_v = fs = 311.2087$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.09037478$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.09037478$
 $v = A_{sl,mid}/(b*d) * (fs_v/f_c) = 0.04381808$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 24.23468$
 $cc (5A.5, TBDY) = 0.00411734$
 $c = \text{confinement factor} = 1.21173$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.1160777$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.1160777$
 $v = A_{sl,mid}/(b*d) * (fs_v/f_c) = 0.0562801$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_s, y_2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.2021744$
 $Mu = MRc (4.14) = 1.1045E+008$
 $u = su (4.1) = 1.7976030E-005$

 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.7976030E-005$$

$$\mu = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

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

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

$$\omega_e ((5.4c), \text{TBDY}) = a_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.14357935$$

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

$$\phi_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$\phi_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t^* \text{Cos}(\beta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} ((5.4d), \text{TBDY}) = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$$

$$p_{sh,x} (5.4d) = 0.00392699$$

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

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

$$b_k = 400.00$$

$$p_{sh,y} (5.4d) = 0.00392699$$

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$ft_1 = 373.4504$$

$$fy_1 = 311.2087$$

$$su_1 = 0.00512$$

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/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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 24.23468

cc (5A.5, TBDY) = 0.00411734

c = confinement factor = 1.21173

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1160777

2 = Asl,com/(b*d)*(fs2/fc) = 0.1160777

v = Asl,mid/(b*d)*(fsv/fc) = 0.0562801

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.2021744

Mu = MRc (4.14) = 1.1045E+008

u = su (4.1) = 1.7976030E-005

Calculation of ratio lb/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:

$$\mu = 1.7976030E-005$$

$$\mu_2 = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu_2: \mu_2^* = \text{shear_factor} * \text{Max}(\mu_2, c_o) = 0.018$$

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

$$\text{From (5.4b), TBDY: } \mu_2 = 0.018$$

$$\mu_{we} \text{ ((5.4c), TBDY)} = a_{se} * \mu_{sh,min} * f_{ywe} / f_{ce} + \text{Min}(\mu_x, \mu_y) = 0.14357935$$

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

$$\mu_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$\mu_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$\mu_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$\mu_{sh,min} = \text{Min}(\mu_{sh,x}, \mu_{sh,y}) = 0.00392699$$

$$\mu_{sh,x} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$\mu_{sh,y} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00411734$$

$c = \text{confinement factor} = 1.21173$
 $y1 = 0.0012967$
 $sh1 = 0.0044814$
 $ft1 = 373.4504$
 $fy1 = 311.2087$
 $su1 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 0.30$
 $su1 = 0.4 * esu1_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu1_nominal = 0.08$,
 For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
 characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs1 = fs = 311.2087$
 with $Es1 = Es = 200000.00$
 $y2 = 0.0012967$
 $sh2 = 0.0044814$
 $ft2 = 373.4504$
 $fy2 = 311.2087$
 $su2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/lb, \min = 0.30$
 $su2 = 0.4 * esu2_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs2 = fs = 311.2087$
 with $Es2 = Es = 200000.00$
 $yv = 0.0012967$
 $shv = 0.0044814$
 $ftv = 373.4504$
 $fyv = 311.2087$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 0.30$
 $suv = 0.4 * esuv_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 311.2087$
 with $Esv = Es = 200000.00$
 $1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.09037478$
 $2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.09037478$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.04381808$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, \text{TBDY}) = 24.23468$
 $cc (5A.5, \text{TBDY}) = 0.00411734$
 $c = \text{confinement factor} = 1.21173$
 $1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.1160777$
 $2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.1160777$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.0562801$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs, y2$ - LHS eq.(4.5) is satisfied

--->

$$\begin{aligned} \mu &= 0.2021744 \\ \mu &= MRC(4.14) = 1.1045E+008 \\ u &= \mu(4.1) = 1.7976030E-005 \end{aligned}$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 524051.339$

Calculation of Shear Strength at edge 1, $V_{r1} = 524051.339$

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

$$V_{Col0} = 524051.339$$

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

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).

$$\begin{aligned} &= 1 \text{ (normal-weight concrete)} \\ f_c' &= 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)} \\ M/Vd &= 2.00 \\ \mu &= 1.8671199E-011 \\ V_u &= 6.9434686E-031 \\ d &= 0.8 * h = 320.00 \\ N_u &= 5926.932 \\ A_g &= 160000.00 \\ \text{From (11.5.4.8), ACI 318-14: } V_s &= 223402.144 \\ A_v &= 157079.633 \\ f_y &= 444.4444 \\ s &= 100.00 \end{aligned}$$

V_s is multiplied by $Col = 1.00$

$$s/d = 0.3125$$

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

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

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

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

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

$$\text{orientation 1: } \theta = 45^\circ \Rightarrow a = 90^\circ = 90.00$$

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

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

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

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 380269.701$$

$$b_w = 400.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 524051.339$

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

$$V_{Col0} = 524051.339$$

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

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).

$$\begin{aligned} &= 1 \text{ (normal-weight concrete)} \\ f_c' &= 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)} \\ M/Vd &= 2.00 \end{aligned}$$

$\mu_u = 1.8671199E-011$
 $V_u = 6.9434686E-031$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 5926.932$
 $A_g = 160000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 223402.144$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.3125$
 V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 357.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 380269.701$
 $b_w = 400.00$

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

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

Constant Properties

 Knowledge Factor, $\lambda = 0.95$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
 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, $f_s = 1.25 \cdot f_{sm} = 555.5556$
 #####
 Section Height, $H = 400.00$
 Section Width, $W = 400.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.21173
 Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou, \text{min}} = 0.30$
 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, $V_a = 4.2515079E-047$
EDGE -B-
Shear Force, $V_b = -4.2515079E-047$
BOTH EDGES
Axial Force, $F = -5926.932$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 829.3805$
-Compression: $As_{c,com} = 829.3805$
-Middle: $As_{mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.14050197$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 73630.246$
with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 1.1045E+008$
 $\mu_{u1+} = 1.1045E+008$, 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
 $\mu_{u1-} = 1.1045E+008$, 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
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 1.1045E+008$
 $\mu_{u2+} = 1.1045E+008$, 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
 $\mu_{u2-} = 1.1045E+008$, 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_{u1+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:
 $\mu_u = 1.7976030E-005$
 $\mu_u = 1.1045E+008$

with full section properties:

$b = 400.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00207526$
 $N = 5926.932$
 $f_c = 20.00$
 $\omega (\text{5A.5, TBDY}) = 0.002$
Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \omega) = 0.018$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\mu_u = 0.018$

w_e ((5.4c), TBDY) = $a_{se} \cdot s_{h,min} \cdot f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$
where $f = a_f \cdot p_f \cdot f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.11712639$
 $a_f = 0.57333333$
 $b = 400.00$
 $h = 400.00$
From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.00508$
 $bw = 400.00$
effective stress from (A.35), $f_{f,e} = 804.2922$

$f_y = 0.11712639$
 $a_f = 0.57333333$
 $b = 400.00$
 $h = 400.00$
From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.00508$
 $bw = 400.00$
effective stress from (A.35), $f_{f,e} = 804.2922$

$R = 40.00$
Effective FRP thickness, $t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 a_{se} ((5.4d), TBDY) = 0.24250288
 $b_o = 340.00$
 $h_o = 340.00$
 $b_{i2} = 462400.00$
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$

$p_{sh,x}$ (5.4d) = 0.00392699
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
No stirups, $n_s = 2.00$
 $b_k = 400.00$

$p_{sh,y}$ (5.4d) = 0.00392699
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
No stirups, $n_s = 2.00$
 $b_k = 400.00$

$s = 100.00$
 $f_{ywe} = 555.5556$
 $f_{ce} = 20.00$
From ((5.A5), TBDY), TBDY: $cc = 0.00411734$
 $c = \text{confinement factor} = 1.21173$
 $y_1 = 0.0012967$
 $sh_1 = 0.0044814$
 $ft_1 = 373.4504$
 $fy_1 = 311.2087$
 $su_1 = 0.00512$
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 $fs_1 = fs = 311.2087$
with $Es_1 = Es = 200000.00$
 $y_2 = 0.0012967$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4504$
 $fy_2 = 311.2087$
 $su_2 = 0.00512$
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

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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 24.23468

cc (5A.5, TBDY) = 0.00411734

c = confinement factor = 1.21173

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1160777

2 = Asl,com/(b*d)*(fs2/fc) = 0.1160777

v = Asl,mid/(b*d)*(fsv/fc) = 0.0562801

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.2021744

Mu = MRc (4.14) = 1.1045E+008

u = su (4.1) = 1.7976030E-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 = 1.7976030E-005

Mu = 1.1045E+008

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00207526

N = 5926.932

fc = 20.00

co (5A.5, TBDY) = 0.002

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

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

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

we ((5.4c), TBDY) = $ase * sh_{,min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.14357935$

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

fx = 0.11712639

af = 0.57333333

b = 400.00

h = 400.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

bw = 400.00

effective stress from (A.35), $ff_{,e} = 804.2922$

fy = 0.11712639

af = 0.57333333

b = 400.00

h = 400.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

bw = 400.00

effective stress from (A.35), $ff_{,e} = 804.2922$

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) = 0.24250288

bo = 340.00

ho = 340.00

bi2 = 462400.00

psh,min = $\text{Min}(psh,x, psh,y) = 0.00392699$

psh,x (5.4d) = 0.00392699

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

No stirups, ns = 2.00

bk = 400.00

psh,y (5.4d) = 0.00392699

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

No stirups, ns = 2.00

bk = 400.00

s = 100.00

fywe = 555.5556

fce = 20.00

From ((5.A5), TBDY), TBDY: $cc = 0.00411734$

c = confinement factor = 1.21173

y1 = 0.0012967

sh1 = 0.0044814

ft1 = 373.4504

fy1 = 311.2087

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 $f_{s1} = f_s = 311.2087$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0012967$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4504$
 $fy_2 = 311.2087$
 $su_2 = 0.00512$
 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 $f_{s2} = f_s = 311.2087$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0012967$
 $sh_v = 0.0044814$
 $ft_v = 373.4504$
 $fy_v = 311.2087$
 $suv = 0.00512$
 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 $f_{sv} = f_s = 311.2087$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.09037478$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.09037478$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.04381808$

and confined core properties:

$b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 24.23468$
 $cc (5A.5, TBDY) = 0.00411734$
 $c = \text{confinement factor} = 1.21173$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.1160777$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.1160777$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.0562801$

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

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

$su (4.9) = 0.2021744$
 $Mu = MRc (4.14) = 1.1045E+008$
 $u = su (4.1) = 1.7976030E-005$

 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.7976030E-005$$

$$Mu = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

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

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

$$\omega_e ((5.4c), TBDY) = \alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.14357935$$

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

$$\phi_x = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$\phi_y = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} ((5.4d), TBDY) = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$\rho_{sh,\min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.00392699$$

$$\rho_{sh,x} (5.4d) = 0.00392699$$

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

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

$$b_k = 400.00$$

$$\rho_{sh,y} (5.4d) = 0.00392699$$

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \alpha_c = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$f_{t1} = 373.4504$$

$$f_{y1} = 311.2087$$

$$s_{u1} = 0.00512$$

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

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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 24.23468

cc (5A.5, TBDY) = 0.00411734

c = confinement factor = 1.21173

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1160777

2 = Asl,com/(b*d)*(fs2/fc) = 0.1160777

v = Asl,mid/(b*d)*(fsv/fc) = 0.0562801

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.2021744

Mu = MRc (4.14) = 1.1045E+008

u = su (4.1) = 1.7976030E-005

Calculation of ratio lb/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:

$$\mu = 1.7976030E-005$$

$$\mu_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

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

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

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$$

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

$$f_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$f_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$$

$$p_{sh,x} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00411734$

$c =$ confinement factor = 1.21173

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

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

with $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0012967$

$sh_2 = 0.0044814$

$ft_2 = 373.4504$

$fy_2 = 311.2087$

$su_2 = 0.00512$

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 $fs_2 = fs = 311.2087$

with $Es_2 = Es = 200000.00$

$y_v = 0.0012967$

$sh_v = 0.0044814$

$ft_v = 373.4504$

$fy_v = 311.2087$

$suv = 0.00512$

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 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 $fsv = fs = 311.2087$

with $Esv = Es = 200000.00$

$1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.09037478$

$2 = Asl,com / (b * d) * (fs_2 / fc) = 0.09037478$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.04381808$

and confined core properties:

$b = 340.00$

$d = 327.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 24.23468$

$cc (5A.5, TBDY) = 0.00411734$

$c =$ confinement factor = 1.21173

$1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.1160777$

$2 = Asl,com / (b * d) * (fs_2 / fc) = 0.1160777$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.0562801$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$\mu (4.9) = 0.2021744$$

$$\mu = M_{Rc} (4.14) = 1.1045E+008$$

$$u = \mu (4.1) = 1.7976030E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 524051.339$

Calculation of Shear Strength at edge 1, $V_{r1} = 524051.339$

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

$$V_{Col0} = 524051.339$$

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

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).

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

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

$$M/Vd = 2.00$$

$$\mu_u = 4.6307395E-012$$

$$V_u = 4.2515079E-047$$

$$d = 0.8 * h = 320.00$$

$$N_u = 5926.932$$

$$A_g = 160000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 223402.144$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

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

$$s/d = 0.3125$$

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

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

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

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

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

$$\text{orientation 1: } \theta_1 = b_1 + 90^\circ = 90.00$$

$$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|), \text{ with:}$$

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

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

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 380269.701$$

$$b_w = 400.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 524051.339$

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

$$V_{Col0} = 524051.339$$

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

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 = 4.6307395E-012

Vu = 4.2515079E-047

d = 0.8*h = 320.00

Nu = 5926.932

Ag = 160000.00

From (11.5.4.8), ACI 318-14: Vs = 223402.144

Av = 157079.633

fy = 444.4444

s = 100.00

Vs is multiplied by Col = 1.00

s/d = 0.3125

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

f = 0.95, for fully-wrapped sections

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

In (11.3) sin + 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) = 357.00

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

Ef = 64828.00

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

with fu = 0.01

From (11-11), ACI 440: Vs + Vf <= 380269.701

bw = 400.00

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, = 0.95

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

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

Consequently:

Existing material of Primary Member: Concrete Strength, fc = fcm = 20.00

Existing material of Primary Member: Steel Strength, fs = fsm = 444.4444

Concrete Elasticity, Ec = 21019.039

Steel Elasticity, Es = 200000.00

Section Height, H = 400.00

Section Width, W = 400.00

Cover Thickness, c = 25.00

Element Length, L = 3000.00

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $E_f = 64828.00$
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, $M = 0.1333213$
Shear Force, $V_2 = 4519.381$
Shear Force, $V_3 = 1.5368441E-013$
Axial Force, $F = -5925.123$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 829.3805$
-Compression: $As_{c,com} = 829.3805$
-Middle: $As_{c,mid} = 402.1239$
Mean Diameter of Tension Reinforcement, $DbL = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.00054405$
 $u = y + p = 0.00057268$

- Calculation of y -

$y = (My * L_s / 3) / E_{eff} = 0.00057268$ ((4.29), Biskinis Phd)
 $My = 7.7038E+007$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.3452E+013$
factor = 0.30
 $A_g = 160000.00$
 $f_c' = 20.00$
 $N = 5925.123$
 $E_c * I_g = 4.4841E+013$

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.8497530E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 248.9669$
 $d = 357.00$
 $y = 0.28100837$
 $A = 0.01459862$
 $B = 0.00825179$
with $pt = 0.00580799$
 $pc = 0.00580799$
 $p_v = 0.00281599$
 $N = 5925.123$
 $b = 400.00$
 $" = 0.12044818$
 $y_{comp} = 1.8620192E-005$
with f_c^* (12.3, (ACI 440)) = 21.65599
 $f_c = 20.00$
 $f_l = 0.93147527$
 $b = 400.00$
 $h = 400.00$

Ag = 160000.00
From (12.9), ACI 440: ka = 0.56708553
g = pt + pc + pv = 0.01443197
rc = 40.00
Ae/Ac = 0.56708553
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 = 0.27898785
A = 0.0143201
B = 0.00808514
with Es = 200000.00

Calculation of ratio lb/d

Inadequate Lap Length with lb/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 lb/d >= 1

shear control ratio VyE/ColOE = 0.14050197

d = 357.00

s = 0.00

t = Av/(bw*s) + 2*tf/bw*(ffe/fs) = 0.00

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

bw = 400.00

The term 2*tf/bw*(ffe/fs) is implemented to account for FRP contribution

where f = 2*tf/bw is FRP ratio (EC8 - 3, A.4.4.3(6)) and ffe/fs normalises f to steel strength

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

NUD = 5925.123

Ag = 160000.00

f'cE = 20.00

fytE = fyIE = 0.00

pl = Area_Tot_Long_Rein/(b*d) = 0.01443197

b = 400.00

d = 357.00

f'cE = 20.00

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

At local axis: 3

Integration Section: (b)

Calculation No. 9

column C1, Floor 1

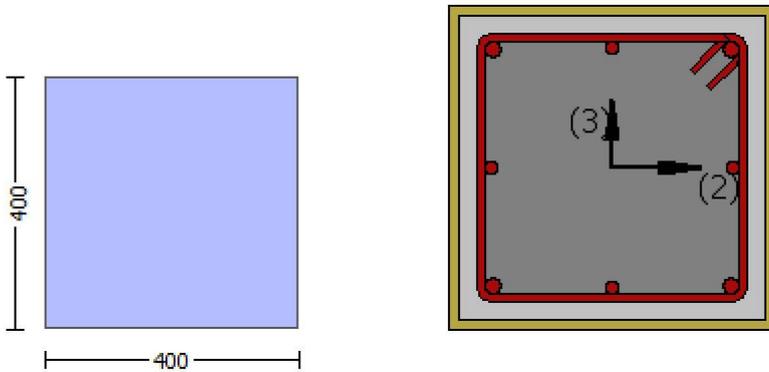
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (2)



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

At local axis: 2

Integration Section: (a)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 0.95$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$

#####

Section Height, $H = 400.00$

Section Width, $W = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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 = -1.6965E+007
Shear Force, Va = -5652.966
EDGE -B-
Bending Moment, Mb = 0.16676193
Shear Force, Vb = 5652.966
BOTH EDGES
Axial Force, F = -5924.669
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 829.3805
-Compression: Asc = 1231.504
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 829.3805
-Compression: Asl,com = 829.3805
-Middle: Asl,mid = 402.1239
Mean Diameter of Tension Reinforcement, DbL,ten = 18.66667

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = V_n = 384262.145$
 V_n ((10.3), ASCE 41-17) = $k_n V_{CoI} = 404486.468$
 $V_{CoI} = 404486.468$
 $k_n = 1.00$
displacement_ductility_demand = 0.06202861

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)
 $M/Vd = 4.00$
 $M_u = 1.6965E+007$
 $V_u = 5652.966$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 5924.669$
 $A_g = 160000.00$
From (11.5.4.8), ACI 318-14: $V_s = 201061.93$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 V_s is multiplied by $CoI = 1.00$
 $s/d = 0.3125$
 V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
total thickness per orientation, $tf1 = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 357.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 340123.561$

bw = 400.00

displacement_ductility_demand is calculated as ϕ_y

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

From analysis, chord rotation $\theta_c = 0.00035536$
 $y = (M_y * L_s / 3) / E_{eff} = 0.00572891$ ((4.29), Biskinis Phd)
 $M_y = 7.7038E+007$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3001.112
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.3452E+013$
factor = 0.30
 $A_g = 160000.00$
 $f_c' = 20.00$
 $N = 5924.669$
 $E_c * I_g = 4.4841E+013$

Calculation of Yielding Moment M_y

Calculation of ϕ_y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.8497516E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / d)^{2/3}) = 248.9669$
 $d = 357.00$
 $y = 0.28100816$
 $A = 0.01459861$
 $B = 0.00825178$
with $pt = 0.00580799$
 $pc = 0.00580799$
 $pv = 0.00281599$
 $N = 5924.669$
 $b = 400.00$
 $" = 0.12044818$
 $y_{comp} = 1.8620196E-005$
with $f_c' (12.3, (ACI 440)) = 21.65599$
 $f_c = 20.00$
 $f_l = 0.93147527$
 $b = 400.00$
 $h = 400.00$
 $A_g = 160000.00$
From (12.9), ACI 440: $k_a = 0.56708553$
 $g = pt + pc + pv = 0.01443197$
 $rc = 40.00$
 $A_e / A_c = 0.56708553$
Effective FRP thickness, $t_f = NL * t * \text{Cos}(b1) = 1.016$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.2789878$
 $A = 0.01432011$
 $B = 0.00808514$
with $E_s = 200000.00$

Calculation of ratio l_b / d

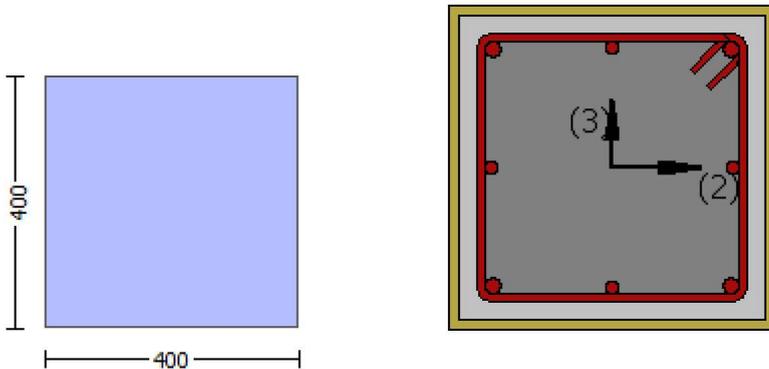
Inadequate Lap Length with $l_b / d = 0.30$

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: Collapse Prevention (data interpolation between analysis steps 1 and 2)
Analysis: Uniform +X
Check: Chord rotation capacity (θ)
Edge: Start
Local Axis: (2)



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

Constant Properties

Knowledge Factor, $\gamma = 0.95$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

Section Height, $H = 400.00$
Section Width, $W = 400.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.21173
Element Length, $L = 3000.00$
Primary Member

Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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, $V_a = -6.9434686E-031$
EDGE -B-
Shear Force, $V_b = 6.9434686E-031$
BOTH EDGES
Axial Force, $F = -5926.932$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{l,ten} = 829.3805$
-Compression: $As_{l,com} = 829.3805$
-Middle: $As_{l,mid} = 402.1239$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.14050197$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 73630.246$
with
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 1.1045E+008$
 $Mu_{1+} = 1.1045E+008$, 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
 $Mu_{1-} = 1.1045E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 1.1045E+008$
 $Mu_{2+} = 1.1045E+008$, 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
 $Mu_{2-} = 1.1045E+008$, 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:
 $\phi_u = 1.7976030E-005$
 $M_u = 1.1045E+008$

with full section properties:
 $b = 400.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00207526$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

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

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

$$\text{we ((5.4c), TBDY)} = a_s e^* s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$$

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

$$f_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$f_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s e \text{ ((5.4d), TBDY)} = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_i^2 = 462400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$$

$$p_{sh,x} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$ft_1 = 373.4504$$

$$fy_1 = 311.2087$$

$$su_1 = 0.00512$$

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

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

$$su_1 = 0.4 * e_{su1_nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } e_{su1_nominal} = 0.08,$$

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.

$$\text{with } f_{s1} = f_s = 311.2087$$

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

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 24.23468

cc (5A.5, TBDY) = 0.00411734

c = confinement factor = 1.21173

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1160777

2 = Asl,com/(b*d)*(fs2/fc) = 0.1160777

v = Asl,mid/(b*d)*(fsv/fc) = 0.0562801

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

su (4.9) = 0.2021744

Mu = MRc (4.14) = 1.1045E+008

u = su (4.1) = 1.7976030E-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 = 1.7976030E-005
Mu = 1.1045E+008

with full section properties:

b = 400.00
d = 357.00
d' = 43.00
v = 0.00207526
N = 5926.932
fc = 20.00
co (5A.5, TBDY) = 0.002

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

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

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

w_e ((5.4c), TBDY) = $ase * sh_{,min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.14357935$

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

fx = 0.11712639
af = 0.57333333
b = 400.00
h = 400.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

bw = 400.00

effective stress from (A.35), $ff_e = 804.2922$

fy = 0.11712639
af = 0.57333333
b = 400.00
h = 400.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

bw = 400.00

effective stress from (A.35), $ff_e = 804.2922$

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) = 0.24250288

bo = 340.00

ho = 340.00

bi2 = 462400.00

$psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00392699$

$psh_{,x}$ (5.4d) = 0.00392699

Ash = $A_{stir} * ns = 78.53982$

No stirups, ns = 2.00

bk = 400.00

$psh_{,y}$ (5.4d) = 0.00392699

Ash = $A_{stir} * ns = 78.53982$

No stirups, ns = 2.00

bk = 400.00

s = 100.00

$fy_{we} = 555.5556$

fce = 20.00

From ((5A5), TBDY), TBDY: $cc = 0.00411734$

c = confinement factor = 1.21173

y1 = 0.0012967

sh1 = 0.0044814

ft1 = 373.4504

fy1 = 311.2087

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

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

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

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

For calculation of $e_{s1_nominal}$ and y_1, sh_1, ft_1, 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.

$$\text{with } f_{s1} = f_s = 311.2087$$

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

$$y_2 = 0.0012967$$

$$sh_2 = 0.0044814$$

$$ft_2 = 373.4504$$

$$fy_2 = 311.2087$$

$$s_u2 = 0.00512$$

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

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

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

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

For calculation of $e_{s2_nominal}$ and y_2, sh_2, ft_2, 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.

$$\text{with } f_{s2} = f_s = 311.2087$$

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

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

$$s_{u,v} = 0.00512$$

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.

$$\text{with } f_{s_{v}} = f_s = 311.2087$$

$$\text{with } E_{s_{v}} = E_s = 200000.00$$

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.09037478$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.09037478$$

$$v = A_{s1,mid}/(b*d) * (f_{s_{v}}/f_c) = 0.04381808$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 24.23468$$

$$c_c (5A.5, TBDY) = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.1160777$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.1160777$$

$$v = A_{s1,mid}/(b*d) * (f_{s_{v}}/f_c) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

$$s_u (4.9) = 0.2021744$$

$$\mu = M_{Rc} (4.14) = 1.1045E+008$$

$$u = s_u (4.1) = 1.7976030E-005$$

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:

$$\mu = 1.7976030E-005$$

$$\mu_{2+} = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

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

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

$$w_{se} \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$$

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

$$f_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$f_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$$

$$p_{sh,x} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 24.23468

cc (5A.5, TBDY) = 0.00411734

c = confinement factor = 1.21173

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1160777

2 = Asl,com/(b*d)*(fs2/fc) = 0.1160777

v = Asl,mid/(b*d)*(fsv/fc) = 0.0562801

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

su (4.9) = 0.2021744
Mu = MRc (4.14) = 1.1045E+008
u = su (4.1) = 1.7976030E-005

Calculation of ratio lb/l_d

Inadequate Lap Length with lb/l_d = 0.30

Calculation of Mu₂-

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

u = 1.7976030E-005
Mu = 1.1045E+008

with full section properties:

b = 400.00
d = 357.00
d' = 43.00
v = 0.00207526
N = 5926.932
f_c = 20.00
co (5A.5, TBDY) = 0.002
Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.018$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_u = 0.018$
 ϕ_{we} ((5.4c), TBDY) = $\text{ase} * \text{sh, min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.14357935$
where $\phi = \text{af} * \text{pf} * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\phi_x = 0.11712639$
 $\text{af} = 0.57333333$
b = 400.00
h = 400.00
From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$
b_w = 400.00
effective stress from (A.35), $f_{f,e} = 804.2922$

 $\phi_y = 0.11712639$
 $\text{af} = 0.57333333$
b = 400.00
h = 400.00
From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$
b_w = 400.00
effective stress from (A.35), $f_{f,e} = 804.2922$

R = 40.00
Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$
f_{u,f} = 1055.00
E_f = 64828.00
u_f = 0.015
ase ((5.4d), TBDY) = 0.24250288
b_o = 340.00
h_o = 340.00
b_{i2} = 462400.00
psh,min = Min(psh,x , psh,y) = 0.00392699

psh,x (5.4d) = 0.00392699
A_{sh} = A_{stir}*n_s = 78.53982
No stirups, n_s = 2.00
b_k = 400.00

psh,y (5.4d) = 0.00392699
A_{sh} = A_{stir}*n_s = 78.53982

No stirrups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
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.

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

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00
d = 327.00
d' = 13.00

fcc (5A.2, TBDY) = 24.23468

cc (5A.5, TBDY) = 0.00411734

c = confinement factor = 1.21173

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1160777$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1160777$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0562801$$

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

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

$$\mu_u(4.9) = 0.2021744$$

$$M_u = M_{Rc}(4.14) = 1.1045E+008$$

$$u = \mu_u(4.1) = 1.7976030E-005$$

 Calculation of ratio l_b/l_d

 Inadequate Lap Length with $l_b/l_d = 0.30$

 Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 524051.339$

 Calculation of Shear Strength at edge 1, $V_{r1} = 524051.339$

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

$$V_{Col0} = 524051.339$$

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

 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).

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

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

$$M/Vd = 2.00$$

$$M_u = 1.8671199E-011$$

$$V_u = 6.9434686E-031$$

$$d = 0.8 * h = 320.00$$

$$N_u = 5926.932$$

$$A_g = 160000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 223402.144$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

$$V_s \text{ is multiplied by } \rho_{col} = 1.00$$

$$s/d = 0.3125$$

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

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

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

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.

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

$$V_f = \text{Min}(|V_f(45, 135)|, |V_f(-45, 135)|), \text{ with:}$$

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

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

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 380269.701$$

$$b_w = 400.00$$

 Calculation of Shear Strength at edge 2, $V_{r2} = 524051.339$

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

$$V_{Col0} = 524051.339$$

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

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 (normal-weight concrete)

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

$M/Vd = 2.00$

$\mu_u = 1.8671199E-011$

$V_u = 6.9434686E-031$

$d = 0.8 \cdot h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = 223402.144$

$A_v = 157079.633$

$f_y = 444.4444$

$s = 100.00$

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

$s/d = 0.3125$

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

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

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

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 380269.701$

$b_w = 400.00$

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

At local axis: 3

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

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\phi = 0.95$

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

Section Height, $H = 400.00$

Section Width, $W = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.21173

Element Length, $L = 3000.00$

Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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: 2
EDGE -A-
Shear Force, $V_a = 4.2515079E-047$
EDGE -B-
Shear Force, $V_b = -4.2515079E-047$
BOTH EDGES
Axial Force, $F = -5926.932$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten} = 829.3805$
-Compression: $A_{st,com} = 829.3805$
-Middle: $A_{st,mid} = 402.1239$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.14050197$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 73630.246$
with

$M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 1.1045E+008$

$Mu_{1+} = 1.1045E+008$, 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

$Mu_{1-} = 1.1045E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 1.1045E+008$

$Mu_{2+} = 1.1045E+008$, 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

$Mu_{2-} = 1.1045E+008$, 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:

$\phi_u = 1.7976030E-005$

$M_u = 1.1045E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$$v = 0.00207526$$

$$N = 5926.932$$

$$fc = 20.00$$

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

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

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

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

$$we \text{ ((5.4c), TBDY)} = ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.14357935$$

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

$$fx = 0.11712639$$

$$af = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ff,e = 804.2922$$

$$fy = 0.11712639$$

$$af = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ff,e = 804.2922$$

$$R = 40.00$$

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

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = 0.24250288$$

$$bo = 340.00$$

$$ho = 340.00$$

$$bi2 = 462400.00$$

$$psh_{min} = \text{Min}(psh,x, psh,y) = 0.00392699$$

$$psh,x \text{ (5.4d)} = 0.00392699$$

$$Ash = Astir * ns = 78.53982$$

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

$$bk = 400.00$$

$$psh,y \text{ (5.4d)} = 0.00392699$$

$$Ash = Astir * ns = 78.53982$$

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

$$bk = 400.00$$

$$s = 100.00$$

$$fy_{we} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$y1 = 0.0012967$$

$$sh1 = 0.0044814$$

$$ft1 = 373.4504$$

$$fy1 = 311.2087$$

$$su1 = 0.00512$$

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.

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

$$\text{with } fs1 = fs = 311.2087$$

with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0012967$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4504$
 $fy_2 = 311.2087$
 $su_2 = 0.00512$
 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 $fs_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 311.2087$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0012967$
 $sh_v = 0.0044814$
 $ft_v = 373.4504$
 $fy_v = 311.2087$
 $suv = 0.00512$
 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 $fs_v = fs_v/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fs_v = fs_v/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_v = fs = 311.2087$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.09037478$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.09037478$
 $v = A_{sl,mid}/(b*d) * (fs_v/f_c) = 0.04381808$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 24.23468$
 $cc (5A.5, TBDY) = 0.00411734$
 $c = \text{confinement factor} = 1.21173$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.1160777$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.1160777$
 $v = A_{sl,mid}/(b*d) * (fs_v/f_c) = 0.0562801$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_s, y_2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.2021744$
 $Mu = MRc (4.14) = 1.1045E+008$
 $u = su (4.1) = 1.7976030E-005$

 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:

$$u = 1.7976030E-005$$

$$Mu = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

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

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

$$\omega_e \text{ ((5.4c), TBDY)} = a_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.14357935$$

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

$$\phi_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$\phi_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t^* \text{Cos}(\beta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$$

$$p_{sh,x} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$ft_1 = 373.4504$$

$$fy_1 = 311.2087$$

$$su_1 = 0.00512$$

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/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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 24.23468

cc (5A.5, TBDY) = 0.00411734

c = confinement factor = 1.21173

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1160777

2 = Asl,com/(b*d)*(fs2/fc) = 0.1160777

v = Asl,mid/(b*d)*(fsv/fc) = 0.0562801

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.2021744

Mu = MRc (4.14) = 1.1045E+008

u = su (4.1) = 1.7976030E-005

Calculation of ratio lb/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:

$$\mu = 1.7976030E-005$$

$$\mu = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

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

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

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$$

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

$$f_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$f_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$$

$$p_{sh,x} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00411734$$

$c = \text{confinement factor} = 1.21173$
 $y1 = 0.0012967$
 $sh1 = 0.0044814$
 $ft1 = 373.4504$
 $fy1 = 311.2087$
 $su1 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.30$
 $su1 = 0.4 * esu1_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu1_nominal = 0.08$,
 For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
 characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs1 = fs = 311.2087$
 with $Es1 = Es = 200000.00$
 $y2 = 0.0012967$
 $sh2 = 0.0044814$
 $ft2 = 373.4504$
 $fy2 = 311.2087$
 $su2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/lb,min = 0.30$
 $su2 = 0.4 * esu2_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs2 = fs = 311.2087$
 with $Es2 = Es = 200000.00$
 $yv = 0.0012967$
 $shv = 0.0044814$
 $ftv = 373.4504$
 $fyv = 311.2087$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.30$
 $suv = 0.4 * esuv_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 311.2087$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.09037478$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.09037478$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.04381808$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, \text{TBDY}) = 24.23468$
 $cc (5A.5, \text{TBDY}) = 0.00411734$
 $c = \text{confinement factor} = 1.21173$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.1160777$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.1160777$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.0562801$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs, y2$ - LHS eq.(4.5) is satisfied

--->

$$s_u(4.9) = 0.2021744$$

$$M_u = M_{Rc}(4.14) = 1.1045E+008$$

$$u = s_u(4.1) = 1.7976030E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_u -----

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

$$u = 1.7976030E-005$$

$$M_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

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

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

$$\phi_{we}((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.14357935$$

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

$$\phi_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$\phi_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se}((5.4d), TBDY) = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$$

$$p_{sh,x}(5.4d) = 0.00392699$$

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

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

$$b_k = 400.00$$

$$p_{sh,y}(5.4d) = 0.00392699$$

Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
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 $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00
d = 327.00
d' = 13.00

fcc (5A.2, TBDY) = 24.23468

cc (5A.5, TBDY) = 0.00411734

$c = \text{confinement factor} = 1.21173$

$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1160777$

$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1160777$

$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0562801$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

$s_u(4.9) = 0.2021744$

$\mu = M_{Rc}(4.14) = 1.1045E+008$

$u = s_u(4.1) = 1.7976030E-005$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 524051.339$

Calculation of Shear Strength at edge 1, $V_{r1} = 524051.339$

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

$V_{Col0} = 524051.339$

$k_{nl} = 1$ (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)

$M/Vd = 2.00$

$\mu = 4.6307395E-012$

$\nu = 4.2515079E-047$

$d = 0.8 * h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = 223402.144$

$A_v = 157079.633$

$f_y = 444.4444$

$s = 100.00$

V_s is multiplied by $Col = 1.00$

$s/d = 0.3125$

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

$f = 0.95$, for fully-wrapped sections

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

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

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

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

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$, with:

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

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 380269.701$

$b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 524051.339$

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

$V_{Col0} = 524051.339$

knl = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)

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

$M/Vd = 2.00$

$\mu_u = 4.6307395E-012$

$\nu_u = 4.2515079E-047$

$d = 0.8 \cdot h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = 223402.144$

$A_v = 157079.633$

$f_y = 444.4444$

$s = 100.00$

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

$s/d = 0.3125$

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

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 380269.701$

$b_w = 400.00$

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: rcrcs

Constant Properties

Knowledge Factor, $\lambda = 0.95$

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

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Section Height, $H = 400.00$

Section Width, $W = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $M = 7.3941089E-010$

Shear Force, $V_2 = -5652.966$

Shear Force, $V_3 = -1.9223267E-013$

Axial Force, $F = -5924.669$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 829.3805$

-Compression: $A_{sc} = 1231.504$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Mean Diameter of Tension Reinforcement, $D_bL = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u,R = * u = 0.04262022$

$u = y + p = 0.04486339$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00286339$ ((4.29), Biskinis Phd)

$M_y = 7.7038E+007$

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

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.3452E+013$

factor = 0.30

$A_g = 160000.00$

$f_c' = 20.00$

$N = 5924.669$

$E_c * I_g = 4.4841E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$y_{ten} = 4.8497516E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b/l_d)^{2/3}) = 248.9669$

$d = 357.00$

$y = 0.28100816$

$A = 0.01459861$

$B = 0.00825178$

with $pt = 0.00580799$

$pc = 0.00580799$

$pv = 0.00281599$

$N = 5924.669$

$b = 400.00$

$\rho = 0.12044818$
 $y_{comp} = 1.8620196E-005$
 with f_c^* (12.3, (ACI 440)) = 21.65599
 $f_c = 20.00$
 $f_l = 0.93147527$
 $b = 400.00$
 $h = 400.00$
 $A_g = 160000.00$
 From (12.9), ACI 440: $k_a = 0.56708553$
 $g = p_t + p_c + p_v = 0.01443197$
 $r_c = 40.00$
 $A_e/A_c = 0.56708553$
 Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.2789878$
 $A = 0.01432011$
 $B = 0.00808514$
 with $E_s = 200000.00$

 Calculation of ratio l_b/d

 Inadequate Lap Length with $l_b/d = 0.30$

 - Calculation of ρ -

 From table 10-8: $\rho = 0.042$

with:

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

shear control ratio $V_y E / V C o l O E = 0.14050197$

$d = 357.00$

$s = 0.00$

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

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

$b_w = 400.00$

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

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

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

$NUD = 5924.669$

$A_g = 160000.00$

$f_c E = 20.00$

$f_{yt} E = f_{yl} E = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.01443197$

$b = 400.00$

$d = 357.00$

$f_c E = 20.00$

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

At local axis: 2

Integration Section: (a)

Calculation No. 11

column C1, Floor 1

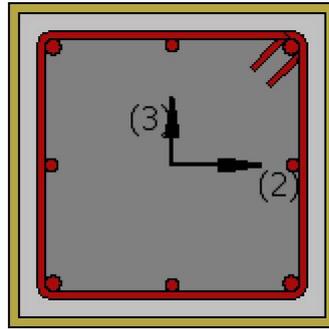
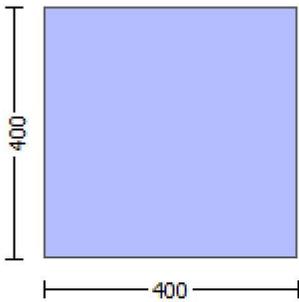
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



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

At local axis: 3

Integration Section: (a)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 0.95$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$

#####

Section Height, $H = 400.00$

Section Width, $W = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = 7.3941089E-010$
Shear Force, $V_a = -1.9223267E-013$
EDGE -B-
Bending Moment, $M_b = -1.6233527E-010$
Shear Force, $V_b = 1.9223267E-013$
BOTH EDGES
Axial Force, $F = -5924.669$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 829.3805$
-Compression: $A_{sl,c} = 1231.504$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 829.3805$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 402.1239$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41-17: Final Shear Capacity $V_R = \phi V_n = 445406.907$
 V_n ((10.3), ASCE 41-17) = $k_n \phi V_{Col} = 468849.376$
 $V_{Col} = 468849.376$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.00$

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)
 $M/Vd = 2.00$
 $\mu_u = 7.3941089E-010$
 $\nu_u = 1.9223267E-013$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 5924.669$
 $A_g = 160000.00$
From (11.5.4.8), ACI 318-14: $V_s = 201061.93$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 V_s is multiplied by $\phi_{Col} = 1.00$
 $s/d = 0.3125$
 V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $\phi = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$, with:

total thickness per orientation, $tf1 = NL*t/NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 357.00
 ffe ((11-5), ACI 440) = 259.312
 $Ef = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
with $fu = 0.01$
From (11-11), ACI 440: $Vs + Vf \leq 340123.561$
 $bw = 400.00$

displacement ductility demand is calculated as δ / y

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

From analysis, chord rotation $\theta = 2.1296969E-020$
 $y = (My*Ls/3)/Eleff = 0.00286339$ ((4.29), Biskinis Phd)
 $My = 7.7038E+007$
 $Ls = M/V$ (with $Ls > 0.1*L$ and $Ls < 2*L$) = 1500.00
From table 10.5, ASCE 41_17: $Eleff = factor*Ec*lg = 1.3452E+013$
 $factor = 0.30$
 $Ag = 160000.00$
 $fc' = 20.00$
 $N = 5924.669$
 $Ec*lg = 4.4841E+013$

Calculation of Yielding Moment My

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

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.8497516E-006$
with ((10.1), ASCE 41-17) $fy = \text{Min}(fy, 1.25*fy*(lb/d)^{2/3}) = 248.9669$
 $d = 357.00$
 $y = 0.28100816$
 $A = 0.01459861$
 $B = 0.00825178$
with $pt = 0.00580799$
 $pc = 0.00580799$
 $pv = 0.00281599$
 $N = 5924.669$
 $b = 400.00$
 $\lambda = 0.12044818$
 $y_{comp} = 1.8620196E-005$
with $fc' = 20.00$ (12.3, (ACI 440)) = 21.65599
 $fl = 0.93147527$
 $b = 400.00$
 $h = 400.00$
 $Ag = 160000.00$
From (12.9), ACI 440: $ka = 0.56708553$
 $g = pt + pc + pv = 0.01443197$
 $rc = 40.00$
 $Ae/Ac = 0.56708553$
Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
effective strain from (12.5) and (12.12), $efe = 0.004$
 $fu = 0.01$
 $Ef = 64828.00$
 $Ec = 21019.039$
 $y = 0.2789878$
 $A = 0.01432011$
 $B = 0.00808514$
with $Es = 200000.00$

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: (a)

Calculation No. 12

column C1, Floor 1

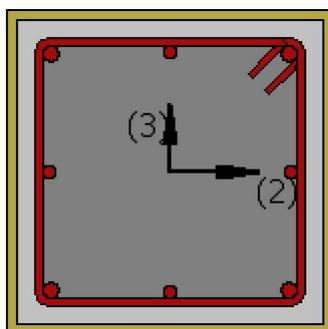
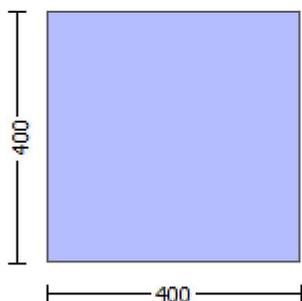
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: Start

Local Axis: (3)



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

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 0.95$

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

Section Height, H = 400.00
Section Width, W = 400.00
Cover Thickness, c = 25.00
Mean Confinement Factor overall section = 1.21173
Element Length, L = 3000.00
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, V_a = -6.9434686E-031
EDGE -B-
Shear Force, V_b = 6.9434686E-031
BOTH EDGES
Axial Force, F = -5926.932
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t}$ = 0.00
-Compression: $A_{sl,c}$ = 2060.885
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten}$ = 829.3805
-Compression: $A_{sl,com}$ = 829.3805
-Middle: $A_{sl,mid}$ = 402.1239

Calculation of Shear Capacity ratio , V_e/V_r = 0.14050197
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 73630.246$
with
 $M_{pr1} = \text{Max}(\mu_{u1+} , \mu_{u1-}) = 1.1045E+008$
 $\mu_{u1+} = 1.1045E+008$, 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
 $\mu_{u1-} = 1.1045E+008$, 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
 $M_{pr2} = \text{Max}(\mu_{u2+} , \mu_{u2-}) = 1.1045E+008$
 $\mu_{u2+} = 1.1045E+008$, 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
 $\mu_{u2-} = 1.1045E+008$, 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:
 $\phi_u = 1.7976030E-005$

Mu = 1.1045E+008

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00207526

N = 5926.932

fc = 20.00

co (5A.5, TBDY) = 0.002

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

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

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

w_e ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$

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

$f_x = 0.11712639$

$af = 0.57333333$

b = 400.00

h = 400.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

bw = 400.00

effective stress from (A.35), $f_{f,e} = 804.2922$

$f_y = 0.11712639$

$af = 0.57333333$

b = 400.00

h = 400.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

bw = 400.00

effective stress from (A.35), $f_{f,e} = 804.2922$

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) = 0.24250288

bo = 340.00

ho = 340.00

$bi^2 = 462400.00$

$psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00392699$

$psh_{,x}$ (5.4d) = 0.00392699

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

No stirups, ns = 2.00

bk = 400.00

$psh_{,y}$ (5.4d) = 0.00392699

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

No stirups, ns = 2.00

bk = 400.00

s = 100.00

$fy_{we} = 555.5556$

fce = 20.00

From ((5A5), TBDY), TBDY: $cc = 0.00411734$

c = confinement factor = 1.21173

$y1 = 0.0012967$

$sh1 = 0.0044814$

$ft1 = 373.4504$

$fy1 = 311.2087$

$su1 = 0.00512$

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

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

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

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

$$\text{with } fs_1 = fs = 311.2087$$

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

$$y_2 = 0.0012967$$

$$sh_2 = 0.0044814$$

$$ft_2 = 373.4504$$

$$fy_2 = 311.2087$$

$$su_2 = 0.00512$$

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

$$lo/lou, \text{min} = lb/lb, \text{min} = 0.30$$

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

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

$$\text{with } fs_2 = fs = 311.2087$$

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

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

$$su_v = 0.00512$$

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

$$lo/lou, \text{min} = lb/ld = 0.30$$

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

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

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

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

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

$$\text{with } fsv = fs = 311.2087$$

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

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.09037478$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.09037478$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.04381808$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 24.23468$$

$$cc (5A.5, TBDY) = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.1160777$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.1160777$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su (4.9) = 0.2021744$$

$$Mu = MRc (4.14) = 1.1045E+008$$

$$u = su (4.1) = 1.7976030E-005$$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Mu1-

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

$$u = 1.7976030E-005$$

$$\text{Mu} = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

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

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

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$$

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

$$f_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$f_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$$

$$p_{sh,x} \text{ (5.4d)} = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$y_1 = 0.0012967$$

$sh1 = 0.0044814$
 $ft1 = 373.4504$
 $fy1 = 311.2087$
 $su1 = 0.00512$
 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 $fs1 = fs = 311.2087$
 with $Es1 = Es = 200000.00$
 $y2 = 0.0012967$
 $sh2 = 0.0044814$
 $ft2 = 373.4504$
 $fy2 = 311.2087$
 $su2 = 0.00512$
 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 $fs2 = fs = 311.2087$
 with $Es2 = Es = 200000.00$
 $yv = 0.0012967$
 $shv = 0.0044814$
 $ftv = 373.4504$
 $fyv = 311.2087$
 $suv = 0.00512$
 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 $fsv = fs = 311.2087$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 24.23468$
 $cc (5A.5, TBDY) = 0.00411734$
 $c = \text{confinement factor} = 1.21173$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.1160777$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.1160777$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.0562801$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs,y2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.2021744$

$$\begin{aligned} \mu &= MRC(4.14) = 1.1045E+008 \\ u &= su(4.1) = 1.7976030E-005 \end{aligned}$$

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:

$$\begin{aligned} u &= 1.7976030E-005 \\ \mu &= 1.1045E+008 \end{aligned}$$

with full section properties:

$$\begin{aligned} b &= 400.00 \\ d &= 357.00 \\ d' &= 43.00 \\ v &= 0.00207526 \\ N &= 5926.932 \\ f_c &= 20.00 \\ c_o(5A.5, TBDY) &= 0.002 \\ \text{Final value of } \mu: \mu^* &= \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.018 \\ \text{The Shear_factor is considered equal to 1 (pure moment strength)} \\ \text{From (5.4b), TBDY: } \mu_c &= 0.018 \\ \mu_{cc}((5.4c), TBDY) &= a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.14357935 \\ \text{where } f &= a_f * p_f * f_{fe}/f_{ce} \text{ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)} \end{aligned}$$

$$\begin{aligned} f_x &= 0.11712639 \\ a_f &= 0.57333333 \\ b &= 400.00 \\ h &= 400.00 \\ \text{From EC8 A.4.4.3(6), } p_f &= 2t_f/b_w = 0.00508 \\ b_w &= 400.00 \\ \text{effective stress from (A.35), } f_{f,e} &= 804.2922 \end{aligned}$$

$$\begin{aligned} f_y &= 0.11712639 \\ a_f &= 0.57333333 \\ b &= 400.00 \\ h &= 400.00 \\ \text{From EC8 A.4.4.3(6), } p_f &= 2t_f/b_w = 0.00508 \\ b_w &= 400.00 \\ \text{effective stress from (A.35), } f_{f,e} &= 804.2922 \end{aligned}$$

$$\begin{aligned} R &= 40.00 \\ \text{Effective FRP thickness, } t_f &= NL * t * \text{Cos}(b_1) = 1.016 \\ f_{u,f} &= 1055.00 \\ E_f &= 64828.00 \\ u_{,f} &= 0.015 \\ a_{se}((5.4d), TBDY) &= 0.24250288 \\ b_o &= 340.00 \\ h_o &= 340.00 \\ b_{i2} &= 462400.00 \\ p_{sh,min} &= \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699 \end{aligned}$$

$$\begin{aligned} p_{sh,x} (5.4d) &= 0.00392699 \\ A_{sh} &= A_{stir} * n_s = 78.53982 \\ \text{No stirups, } n_s &= 2.00 \\ b_k &= 400.00 \end{aligned}$$

$$\begin{aligned} p_{sh,y} (5.4d) &= 0.00392699 \\ A_{sh} &= A_{stir} * n_s = 78.53982 \\ \text{No stirups, } n_s &= 2.00 \end{aligned}$$

bk = 400.00

s = 100.00

fywe = 555.5556

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00411734

c = confinement factor = 1.21173

y1 = 0.0012967

sh1 = 0.0044814

ft1 = 373.4504

fy1 = 311.2087

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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 24.23468

cc (5A.5, TBDY) = 0.00411734

c = confinement factor = 1.21173

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1160777

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.1160777$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

---->

$$s_u(4.9) = 0.2021744$$

$$M_u = M_{Rc}(4.14) = 1.1045E+008$$

$$u = s_u(4.1) = 1.7976030E-005$$

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:

$$u = 1.7976030E-005$$

$$M_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

$$\alpha(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.018$$

$$\phi_{cc} \text{ ((5.4c), TBDY) } = \alpha_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.14357935$$

where $\phi_f = \alpha_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$\phi_{fy} = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TBDY) } = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$$

psh,x (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

psh,y (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478
2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478
v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 24.23468$$

$$cc (5A.5, TBDY) = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1160777$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1160777$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.2021744$$

$$M_u = MR_c (4.14) = 1.1045E+008$$

$$u = s_u (4.1) = 1.7976030E-005$$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 524051.339$

Calculation of Shear Strength at edge 1, $V_{r1} = 524051.339$

$$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$$

$$V_{Col0} = 524051.339$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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)

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$M_u = 1.8671199E-011$$

$$V_u = 6.9434686E-031$$

$$d = 0.8 * h = 320.00$$

$$N_u = 5926.932$$

$$A_g = 160000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 223402.144$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

V_s is multiplied by $\text{Col} = 1.00$

$$s/d = 0.3125$$

$$V_f ((11-3)-(11.4), ACI 440) = 188111.148$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,

where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

$$\text{orientation 1: } \theta = 45^\circ + 90^\circ = 135^\circ$$

$$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = N_L * t / N_{oDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 357.00$$

$$f_{fe} ((11-5), ACI 440) = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 380269.701$$

bw = 400.00

Calculation of Shear Strength at edge 2, Vr2 = 524051.339

Vr2 = VCol ((10.3), ASCE 41-17) = knl*VCol0

VCol0 = 524051.339

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 = 1.8671199E-011

Vu = 6.9434686E-031

d = 0.8*h = 320.00

Nu = 5926.932

Ag = 160000.00

From (11.5.4.8), ACI 318-14: Vs = 223402.144

Av = 157079.633

fy = 444.4444

s = 100.00

Vs is multiplied by Col = 1.00

s/d = 0.3125

Vf ((11-3)-(11.4), ACI 440) = 188111.148

f = 0.95, for fully-wrapped sections

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(θ), is implemented for every different fiber orientation ai, as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

Vf = Min(|Vf(45, 1)|, |Vf(-45,a1)|), with:

total thickness per orientation, tf1 = NL*t/NoDir = 1.016

dfv = d (figure 11.2, ACI 440) = 357.00

ffe ((11-5), ACI 440) = 259.312

Ef = 64828.00

fe = 0.004, from (11.6a), ACI 440

with fu = 0.01

From (11-11), ACI 440: Vs + Vf <= 380269.701

bw = 400.00

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\phi = 0.95$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, fc = fcm = 20.00

Existing material of Primary Member: Steel Strength, fs = fsm = 444.4444

Concrete Elasticity, Ec = 21019.039

Steel Elasticity, Es = 200000.00

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$

Section Height, $H = 400.00$
Section Width, $W = 400.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.21173
Element Length, $L = 3000.00$
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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: 2
EDGE -A-
Shear Force, $V_a = 4.2515079E-047$
EDGE -B-
Shear Force, $V_b = -4.2515079E-047$
BOTH EDGES
Axial Force, $F = -5926.932$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten} = 829.3805$
-Compression: $A_{st,com} = 829.3805$
-Middle: $A_{st,mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.14050197$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 73630.246$
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.1045E+008$
 $M_{u1+} = 1.1045E+008$, 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
 $M_{u1-} = 1.1045E+008$, 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
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.1045E+008$
 $M_{u2+} = 1.1045E+008$, 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
 $M_{u2-} = 1.1045E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment
direction which is defined for the the static loading combination

Calculation of M_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

u = 1.7976030E-005
Mu = 1.1045E+008

with full section properties:

b = 400.00
d = 357.00
d' = 43.00
v = 0.00207526
N = 5926.932
fc = 20.00
co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.018$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.018$

w_e ((5.4c), TBDY) = $ase * sh_{\min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.14357935$

where $f = af * pf * ff_e / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.11712639
af = 0.57333333
b = 400.00
h = 400.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

bw = 400.00

effective stress from (A.35), $ff_e = 804.2922$

fy = 0.11712639
af = 0.57333333
b = 400.00
h = 400.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

bw = 400.00

effective stress from (A.35), $ff_e = 804.2922$

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) = 0.24250288

bo = 340.00

ho = 340.00

bi2 = 462400.00

$psh_{\min} = \text{Min}(psh_x, psh_y) = 0.00392699$

psh_x (5.4d) = 0.00392699

Ash = $A_{stir} * ns = 78.53982$

No stirups, ns = 2.00

bk = 400.00

psh_y (5.4d) = 0.00392699

Ash = $A_{stir} * ns = 78.53982$

No stirups, ns = 2.00

bk = 400.00

s = 100.00

$fy_{we} = 555.5556$

fce = 20.00

From ((5A5), TBDY), TBDY: $cc = 0.00411734$

c = confinement factor = 1.21173

y1 = 0.0012967

sh1 = 0.0044814

ft1 = 373.4504

fy1 = 311.2087

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

$$l_o/l_{o,u,min} = l_b/l_d = 0.30$$

$$s_u1 = 0.4 * e_{s1_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s1_nominal} = 0.08$,

For calculation of $e_{s1_nominal}$ and y_1, sh_1, ft_1, 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.

$$\text{with } f_{s1} = f_s = 311.2087$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.0012967$$

$$sh_2 = 0.0044814$$

$$ft_2 = 373.4504$$

$$fy_2 = 311.2087$$

$$s_u2 = 0.00512$$

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

$$l_o/l_{o,u,min} = l_b/l_{b,min} = 0.30$$

$$s_u2 = 0.4 * e_{s2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s2_nominal} = 0.08$,

For calculation of $e_{s2_nominal}$ and y_2, sh_2, ft_2, 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.

$$\text{with } f_{s2} = f_s = 311.2087$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

$$s_{u,v} = 0.00512$$

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.

$$\text{with } f_{s_{v}} = f_s = 311.2087$$

$$\text{with } E_{s_{v}} = E_s = 200000.00$$

$$1 = A_{s1,ten}/(b * d) * (f_{s1}/f_c) = 0.09037478$$

$$2 = A_{s1,com}/(b * d) * (f_{s2}/f_c) = 0.09037478$$

$$v = A_{s1,mid}/(b * d) * (f_{s_{v}}/f_c) = 0.04381808$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 24.23468$$

$$c_c (5A.5, TBDY) = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = A_{s1,ten}/(b * d) * (f_{s1}/f_c) = 0.1160777$$

$$2 = A_{s1,com}/(b * d) * (f_{s2}/f_c) = 0.1160777$$

$$v = A_{s1,mid}/(b * d) * (f_{s_{v}}/f_c) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

$$s_u (4.9) = 0.2021744$$

$$\mu = M_{Rc} (4.14) = 1.1045E+008$$

$$u = s_u (4.1) = 1.7976030E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Mu1-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.7976030E-005$$

$$Mu = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

$$cc \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.018$$

$$w_e \text{ ((5.4c), TBDY)} = ase * sh_{,min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.11712639$$

$$af = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ff_{,e} = 804.2922$$

$$f_y = 0.11712639$$

$$af = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ff_{,e} = 804.2922$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } tf = NL * t * \text{Cos}(b1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$bi_2 = 462400.00$$

$$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00392699$$

$$psh_x \text{ (5.4d)} = 0.00392699$$

$$Ash = Astir * ns = 78.53982$$

$$\text{No stirups, } ns = 2.00$$

$$bk = 400.00$$

$$psh_y \text{ (5.4d)} = 0.00392699$$

$$Ash = Astir * ns = 78.53982$$

$$\text{No stirups, } ns = 2.00$$

$$bk = 400.00$$

$$s = 100.00$$

$$fy_{we} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 24.23468

cc (5A.5, TBDY) = 0.00411734

c = confinement factor = 1.21173

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1160777

2 = Asl,com/(b*d)*(fs2/fc) = 0.1160777

v = Asl,mid/(b*d)*(fsv/fc) = 0.0562801

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

v < vs,y2 - LHS eq.(4.5) is satisfied

---->

su (4.9) = 0.2021744
Mu = MRc (4.14) = 1.1045E+008
u = su (4.1) = 1.7976030E-005

Calculation of ratio lb/l_d

Inadequate Lap Length with lb/l_d = 0.30

Calculation of Mu₂₊

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

u = 1.7976030E-005
Mu = 1.1045E+008

with full section properties:

b = 400.00
d = 357.00
d' = 43.00
v = 0.00207526
N = 5926.932
f_c = 20.00
co (5A.5, TBDY) = 0.002
Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.018$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_u = 0.018$
 ϕ_{we} ((5.4c), TBDY) = $\text{ase} * \text{sh}_{,\text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.14357935$
where $\phi = \text{af} * \text{pf} * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\phi_x = 0.11712639$
 $\text{af} = 0.57333333$
b = 400.00
h = 400.00
From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$
b_w = 400.00
effective stress from (A.35), $f_{f,e} = 804.2922$

 $\phi_y = 0.11712639$
 $\text{af} = 0.57333333$
b = 400.00
h = 400.00
From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$
b_w = 400.00
effective stress from (A.35), $f_{f,e} = 804.2922$

R = 40.00
Effective FRP thickness, $t_f = \text{NL} * t * \text{Cos}(b_1) = 1.016$
f_{u,f} = 1055.00
E_f = 64828.00
u_f = 0.015
ase ((5.4d), TBDY) = 0.24250288
b_o = 340.00
h_o = 340.00
b_{i2} = 462400.00
psh_{,min} = Min(psh_{,x}, psh_{,y}) = 0.00392699

psh_{,x} (5.4d) = 0.00392699
A_{sh} = A_{stir} * n_s = 78.53982
No stirups, n_s = 2.00
b_k = 400.00

psh_{,y} (5.4d) = 0.00392699
A_{sh} = A_{stir} * n_s = 78.53982

No stirrups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
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.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00
d = 327.00
d' = 13.00

fcc (5A.2, TBDY) = 24.23468

cc (5A.5, TBDY) = 0.00411734

c = confinement factor = 1.21173

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1160777$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1160777$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture
satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

$$s_u(4.9) = 0.2021744$$

$$M_u = M_{Rc}(4.14) = 1.1045E+008$$

$$u = s_u(4.1) = 1.7976030E-005$$

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:

$$u = 1.7976030E-005$$

$$M_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

$$\alpha(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.018$$

$$\omega_e \text{ ((5.4c), TBDY) } = \alpha_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.14357935$$

where $\phi = \alpha_{pf} * p_f / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$\phi_y = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TBDY) } = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$$

psh,x (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

psh,y (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173

y1 = 0.0012967
sh1 = 0.0044814

ft1 = 373.4504

fy1 = 311.2087

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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.04381808$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 24.23468$
 $cc (5A.5, TBDY) = 0.00411734$
 $c = \text{confinement factor} = 1.21173$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1160777$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1160777$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0562801$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $\mu (4.9) = 0.2021744$
 $\mu = M_{Rc} (4.14) = 1.1045E+008$
 $u = \mu (4.1) = 1.7976030E-005$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 524051.339$

Calculation of Shear Strength at edge 1, $V_{r1} = 524051.339$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$

$V_{Col0} = 524051.339$

$k_{nl} = 1$ (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)

$M/d = 2.00$

$\mu_u = 4.6307395E-012$

$V_u = 4.2515079E-047$

$d = 0.8 * h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = 223402.144$

$A_v = 157079.633$

$f_y = 444.4444$

$s = 100.00$

V_s is multiplied by $\text{Col} = 1.00$

$s/d = 0.3125$

$V_f ((11-3)-(11.4), ACI 440) = 188111.148$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different cyclic fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

$f_{fe} ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 380269.701$
 $bw = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 524051.339$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Col0}$
 $V_{Col0} = 524051.339$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

 $k = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 4.6307395E-012$

$V_u = 4.2515079E-047$

$d = 0.8 * h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = 223402.144$

$A_v = 157079.633$

$f_y = 444.4444$

$s = 100.00$

V_s is multiplied by $Col = 1.00$

$s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 188111.148

$f = 0.95$, for fully-wrapped sections

$w_f / s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 380269.701$

$bw = 400.00$

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, $k = 0.95$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Section Height, $H = 400.00$

Section Width, $W = 400.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 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, $M = -1.6965E+007$
 Shear Force, $V2 = -5652.966$
 Shear Force, $V3 = -1.9223267E-013$
 Axial Force, $F = -5924.669$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{st} = 829.3805$
 -Compression: $A_{sc} = 1231.504$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{st,ten} = 829.3805$
 -Compression: $A_{st,com} = 829.3805$
 -Middle: $A_{st,mid} = 402.1239$
 Mean Diameter of Tension Reinforcement, $DbL = 18.66667$

 Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \rho \cdot u = 0.04534246$
 $u = \rho \cdot y + p = 0.04772891$

 - Calculation of y -

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00572891$ ((4.29), Biskinis Phd))
 $M_y = 7.7038E+007$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 3001.112
 From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 1.3452E+013$
 factor = 0.30
 $A_g = 160000.00$
 $f_c' = 20.00$
 $N = 5924.669$
 $E_c \cdot I_g = 4.4841E+013$

 Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.8497516E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/l_d)^{2/3}) = 248.9669$
 $d = 357.00$
 $y = 0.28100816$

A = 0.01459861
 B = 0.00825178
 with $p_t = 0.00580799$
 $p_c = 0.00580799$
 $p_v = 0.00281599$
 N = 5924.669
 b = 400.00
 $\alpha = 0.12044818$
 $y_{comp} = 1.8620196E-005$
 with f_c^* (12.3, (ACI 440)) = 21.65599
 $f_c = 20.00$
 $f_l = 0.93147527$
 b = 400.00
 h = 400.00
 $A_g = 160000.00$
 From (12.9), ACI 440: $k_a = 0.56708553$
 $g = p_t + p_c + p_v = 0.01443197$
 $r_c = 40.00$
 $A_e/A_c = 0.56708553$
 Effective FRP thickness, $t_f = N L \alpha \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.2789878$
 A = 0.01432011
 B = 0.00808514
 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: $p = 0.042$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
 shear control ratio $V_y E / V_{CoI} E = 0.14050197$

$d = 357.00$

$s = 0.00$

$t = A_v / (b_w \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00$

$A_v = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$b_w = 400.00$

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ is implemented to account for FRP contribution

where $f = 2 \cdot t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

NUD = 5924.669

$A_g = 160000.00$

$f_c E = 20.00$

$f_{yt} E = f_{yl} E = 0.00$

$p_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.01443197$

b = 400.00

d = 357.00

$f_c E = 20.00$

 End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 13

column C1, Floor 1

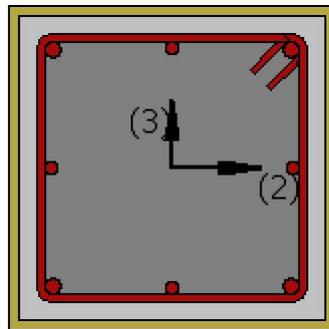
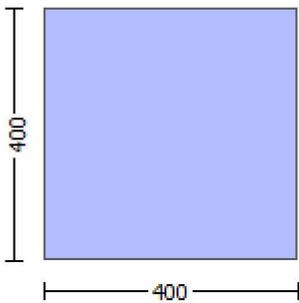
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 0.95$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$

#####

Section Height, $H = 400.00$

Section Width, $W = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $NoDir = 1$

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, $M_a = -1.6965E+007$

Shear Force, $V_a = -5652.966$

EDGE -B-

Bending Moment, $M_b = 0.16676193$

Shear Force, $V_b = 5652.966$

BOTH EDGES

Axial Force, $F = -5924.669$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 829.3805$

-Compression: $A_{sl,com} = 829.3805$

-Middle: $A_{sl,mid} = 402.1239$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 445406.907$

V_n ((10.3), ASCE 41-17) = $k_n \phi V_{Col} = 468849.376$

$V_{Col} = 468849.376$

$k_n = 1.00$

$displacement_ductility_demand = 0.33029499$

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)

$M/Vd = 2.00$

$M_u = 0.16676193$

$V_u = 5652.966$

$d = 0.8 \cdot h = 320.00$

$N_u = 5924.669$

$A_g = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = 201061.93$

$A_v = 157079.633$

$f_y = 400.00$

$s = 100.00$

V_s is multiplied by $\phi_{Col} = 1.00$

$s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 188111.148

$\phi = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \theta$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \phi)$, 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: $\theta = b1 + 90^\circ = 90.00$
Vf = Min(|Vf(45, 1)|, |Vf(-45, a1)|), with:
total thickness per orientation, $tf1 = NL*t/NoDir = 1.016$
dfv = d (figure 11.2, ACI 440) = 357.00
ffe ((11-5), ACI 440) = 259.312
Ef = 64828.00
fe = 0.004, from (11.6a), ACI 440
with fu = 0.01
From (11-11), ACI 440: $Vs + Vf \leq 340123.561$
bw = 400.00

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 $\theta = 0.00018915$
 $y = (My*Ls/3)/Eleff = 0.00057268$ ((4.29), Biskinis Phd))
My = 7.7038E+007
Ls = M/V (with $Ls > 0.1*L$ and $Ls < 2*L$) = 300.00
From table 10.5, ASCE 41_17: $Eleff = factor*Ec*Ig = 1.3452E+013$
factor = 0.30
Ag = 160000.00
fc' = 20.00
N = 5924.669
Ec*Ig = 4.4841E+013

Calculation of Yielding Moment My

Calculation of δ / y and My according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.8497516E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25*f_y*(l_b/d)^{2/3}) = 248.9669$
d = 357.00
y = 0.28100816
A = 0.01459861
B = 0.00825178
with pt = 0.00580799
pc = 0.00580799
pv = 0.00281599
N = 5924.669
b = 400.00
" = 0.12044818
 $y_{comp} = 1.8620196E-005$
with fc* (12.3, (ACI 440)) = 21.65599
fc = 20.00
fl = 0.93147527
b = 400.00
h = 400.00
Ag = 160000.00
From (12.9), ACI 440: $k_a = 0.56708553$
g = pt + pc + pv = 0.01443197
rc = 40.00
Ae/Ac = 0.56708553
Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
effective strain from (12.5) and (12.12), efe = 0.004
fu = 0.01
Ef = 64828.00
Ec = 21019.039
y = 0.2789878
A = 0.01432011
B = 0.00808514

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. 14

column C1, Floor 1

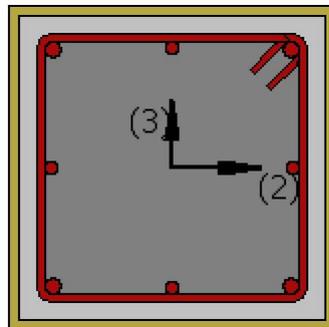
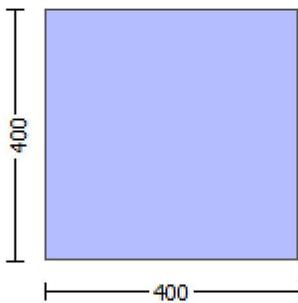
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 0.95$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

Section Height, $H = 400.00$

Section Width, $W = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.21173

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $V_a = -6.9434686E-031$

EDGE -B-

Shear Force, $V_b = 6.9434686E-031$

BOTH EDGES

Axial Force, $F = -5926.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 829.3805$

-Compression: $As_{l,com} = 829.3805$

-Middle: $As_{l,mid} = 402.1239$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.14050197$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 73630.246$

with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 1.1045E+008$

$\mu_{1+} = 1.1045E+008$, 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

$\mu_{1-} = 1.1045E+008$, 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 1.1045E+008$

$\mu_{2+} = 1.1045E+008$, 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

$\mu_{2-} = 1.1045E+008$, 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:

$$u = 1.7976030E-005$$

$$Mu = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

$$\alpha (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.018$$

$$\omega_e \text{ ((5.4c), TBDY) } = \alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.14357935$$

where $\phi = \alpha * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$\phi_y = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(\beta_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$\alpha_s \text{ ((5.4d), TBDY) } = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$\rho_{sh,\min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.00392699$$

$$\rho_{sh,x} \text{ (5.4d) } = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$\rho_{sh,y} \text{ (5.4d) } = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$ft_1 = 373.4504$$

$$fy_1 = 311.2087$$

$$su_1 = 0.00512$$

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/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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 24.23468

cc (5A.5, TBDY) = 0.00411734

c = confinement factor = 1.21173

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1160777

2 = Asl,com/(b*d)*(fs2/fc) = 0.1160777

v = Asl,mid/(b*d)*(fsv/fc) = 0.0562801

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

v < vs,y2 - LHS eq.(4.5) is satisfied

su (4.9) = 0.2021744

Mu = MRc (4.14) = 1.1045E+008

u = su (4.1) = 1.7976030E-005

Calculation of ratio lb/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:

$$\mu = 1.7976030E-005$$

$$\mu_1 = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$f_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$$

$$p_{sh,x} \text{ (5.4d)} = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00411734$$

$c = \text{confinement factor} = 1.21173$
 $y1 = 0.0012967$
 $sh1 = 0.0044814$
 $ft1 = 373.4504$
 $fy1 = 311.2087$
 $su1 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.30$
 $su1 = 0.4*esu1_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu1_nominal = 0.08$,
 For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
 characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs1 = fs = 311.2087$
 with $Es1 = Es = 200000.00$
 $y2 = 0.0012967$
 $sh2 = 0.0044814$
 $ft2 = 373.4504$
 $fy2 = 311.2087$
 $su2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/lb,min = 0.30$
 $su2 = 0.4*esu2_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs2 = fs = 311.2087$
 with $Es2 = Es = 200000.00$
 $yv = 0.0012967$
 $shv = 0.0044814$
 $ftv = 373.4504$
 $fyv = 311.2087$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.30$
 $suv = 0.4*esuv_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 311.2087$
 with $Esv = Es = 200000.00$
 $1 = \text{Asl,ten}/(b*d)*(fs1/fc) = 0.09037478$
 $2 = \text{Asl,com}/(b*d)*(fs2/fc) = 0.09037478$
 $v = \text{Asl,mid}/(b*d)*(fsv/fc) = 0.04381808$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, \text{TBDY}) = 24.23468$
 $cc (5A.5, \text{TBDY}) = 0.00411734$
 $c = \text{confinement factor} = 1.21173$
 $1 = \text{Asl,ten}/(b*d)*(fs1/fc) = 0.1160777$
 $2 = \text{Asl,com}/(b*d)*(fs2/fc) = 0.1160777$
 $v = \text{Asl,mid}/(b*d)*(fsv/fc) = 0.0562801$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs, y2$ - LHS eq.(4.5) is satisfied

--->

$$s_u(4.9) = 0.2021744$$

$$M_u = M_{Rc}(4.14) = 1.1045E+008$$

$$u = s_u(4.1) = 1.7976030E-005$$

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:

$$u = 1.7976030E-005$$

$$M_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.018$$

$$\phi_{we}((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.14357935$$

where $\phi_f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$\phi_{fy} = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se}((5.4d), TBDY) = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$$

$$p_{sh,x}(5.4d) = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$p_{sh,y}(5.4d) = 0.00392699$$

Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00
d = 327.00
d' = 13.00

fcc (5A.2, TBDY) = 24.23468

cc (5A.5, TBDY) = 0.00411734

c = confinement factor = 1.21173

1 = $Asl,ten/(b*d)*(fs1/fc) = 0.1160777$

2 = $Asl,com/(b*d)*(fs2/fc) = 0.1160777$

v = $Asl,mid/(b*d)*(fsv/fc) = 0.0562801$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

v < vs,y2 - LHS eq.(4.5) is satisfied

su (4.9) = 0.2021744

Mu = MRc (4.14) = 1.1045E+008

u = su (4.1) = 1.7976030E-005

Calculation of ratio lb/l_d

Inadequate Lap Length with lb/l_d = 0.30

Calculation of Mu₂-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.7976030E-005

Mu = 1.1045E+008

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00207526

N = 5926.932

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = shear_factor * Max(cu, cc) = 0.018$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.018

we ((5.4c), TBDY) = $ase * sh,min*fywe/fce + Min(fx, fy) = 0.14357935$

where f = $af*pf*ffe/fce$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.11712639

af = 0.57333333

b = 400.00

h = 400.00

From EC8 A.4.4.3(6), pf = $2tf/bw = 0.00508$

bw = 400.00

effective stress from (A.35), ff,e = 804.2922

fy = 0.11712639

af = 0.57333333

b = 400.00

h = 400.00

From EC8 A.4.4.3(6), pf = $2tf/bw = 0.00508$

bw = 400.00

effective stress from (A.35), ff,e = 804.2922

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) = 0.24250288

bo = 340.00

ho = 340.00

bi2 = 462400.00

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00392699$$

$$psh,x (5.4d) = 0.00392699$$

$$\text{Ash} = \text{Astir} * ns = 78.53982$$

$$\text{No stirups, ns} = 2.00$$

$$bk = 400.00$$

$$psh,y (5.4d) = 0.00392699$$

$$\text{Ash} = \text{Astir} * ns = 78.53982$$

$$\text{No stirups, ns} = 2.00$$

$$bk = 400.00$$

$$s = 100.00$$

$$fywe = 555.5556$$

$$fce = 20.00$$

$$\text{From } ((5.A5), \text{TBDY}), \text{TBDY: } cc = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$y1 = 0.0012967$$

$$sh1 = 0.0044814$$

$$ft1 = 373.4504$$

$$fy1 = 311.2087$$

$$su1 = 0.00512$$

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

$$lo/lou,min = lb/d = 0.30$$

$$su1 = 0.4 * esu1_nominal ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_nominal = 0.08,$$

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

$$y1, sh1,ft1,fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/d)^{2/3}), \text{ from 10.3.5, ASCE41-17.}$$

$$\text{with } fs1 = fs = 311.2087$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.0012967$$

$$sh2 = 0.0044814$$

$$ft2 = 373.4504$$

$$fy2 = 311.2087$$

$$su2 = 0.00512$$

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

$$lo/lou,min = lb/lb,min = 0.30$$

$$su2 = 0.4 * esu2_nominal ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_nominal = 0.08,$$

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

$$y1, sh1,ft1,fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/d)^{2/3}), \text{ from 10.3.5, ASCE41-17.}$$

$$\text{with } fs2 = fs = 311.2087$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.0012967$$

$$shv = 0.0044814$$

$$ftv = 373.4504$$

$$fyv = 311.2087$$

$$suv = 0.00512$$

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

$$lo/lou,min = lb/d = 0.30$$

$$suv = 0.4 * esuv_nominal ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } esuv_nominal = 0.08,$$

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

$$y1, sh1,ft1,fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/d)^{2/3}), \text{ from 10.3.5, ASCE41-17.}$$

$$\text{with } fsv = fs = 311.2087$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = \text{Asl,ten}/(b*d) * (fs1/fc) = 0.09037478$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09037478$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.04381808$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 24.23468$$

$$c_c (5A.5, TBDY) = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1160777$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1160777$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$\mu_u (4.9) = 0.2021744$$

$$\mu_u = M/R_c (4.14) = 1.1045E+008$$

$$u = \mu_u (4.1) = 1.7976030E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 524051.339$

Calculation of Shear Strength at edge 1, $V_{r1} = 524051.339$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$

$$V_{Col0} = 524051.339$$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_{s+} = f * V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$\rho = 1$ (normal-weight concrete)

$$f_c' = 20.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/V_d = 2.00$$

$$\mu_u = 1.8671199E-011$$

$$V_u = 6.9434686E-031$$

$$d = 0.8 * h = 320.00$$

$$N_u = 5926.932$$

$$A_g = 160000.00$$

From (11.5.4.8), ACI 318-14: $V_s = 223402.144$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

V_s is multiplied by $\rho_{col} = 1.00$

$$s/d = 0.3125$$

$$V_f ((11-3)-(11.4), ACI 440) = 188111.148$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

$$\text{orientation 1: } \theta = 45^\circ + 90^\circ = 135^\circ$$

$$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, 1)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = N_L * t / N_{oDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 357.00$$

$$f_{fe} ((11-5), ACI 440) = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 380269.701$
 $bw = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 524051.339$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l * V_{Col0}$
 $V_{Col0} = 524051.339$
 $k_n l = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

 $= 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M / V d = 2.00$
 $\mu_u = 1.8671199E-011$
 $V_u = 6.9434686E-031$
 $d = 0.8 * h = 320.00$
 $N_u = 5926.932$
 $A_g = 160000.00$
From (11.5.4.8), ACI 318-14: $V_s = 223402.144$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$

V_s is multiplied by $Col = 1.00$
 $s / d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 188111.148

$f = 0.95$, for fully-wrapped sections
 $w_f / s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 380269.701$
 $bw = 400.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\phi = 0.95$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

Section Height, $H = 400.00$

Section Width, $W = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.21173

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $V_a = 4.2515079E-047$

EDGE -B-

Shear Force, $V_b = -4.2515079E-047$

BOTH EDGES

Axial Force, $F = -5926.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 829.3805$

-Compression: $A_{sl,com} = 829.3805$

-Middle: $A_{sl,mid} = 402.1239$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.14050197$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 73630.246$

with

$M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 1.1045E+008$

$M_{u1+} = 1.1045E+008$, 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

$M_{u1-} = 1.1045E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 1.1045E+008$

$M_{u2+} = 1.1045E+008$, 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

$M_{u2-} = 1.1045E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of M_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.7976030E-005$$

$$Mu = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

$$\alpha (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.018$$

$$\omega_e \text{ ((5.4c), TBDY) } = \alpha s e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.14357935$$

where $\phi = \alpha * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$\phi_y = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha s e \text{ ((5.4d), TBDY) } = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$\rho_{sh,\min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.00392699$$

$$\rho_{sh,x} \text{ (5.4d) } = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$\rho_{sh,y} \text{ (5.4d) } = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$f_{t1} = 373.4504$$

$$f_{y1} = 311.2087$$

$$s_{u1} = 0.00512$$

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

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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 24.23468

cc (5A.5, TBDY) = 0.00411734

c = confinement factor = 1.21173

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1160777

2 = Asl,com/(b*d)*(fs2/fc) = 0.1160777

v = Asl,mid/(b*d)*(fsv/fc) = 0.0562801

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.2021744

Mu = MRc (4.14) = 1.1045E+008

u = su (4.1) = 1.7976030E-005

Calculation of ratio lb/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:

$$\mu_u = 1.7976030E-005$$

$$\mu_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, c_o) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.018$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$f_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$$

$$p_{sh,x} \text{ (5.4d)} = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00411734$

$c =$ confinement factor = 1.21173

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

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 $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0012967$

$sh_2 = 0.0044814$

$ft_2 = 373.4504$

$fy_2 = 311.2087$

$su_2 = 0.00512$

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 $fs_2 = fs = 311.2087$

with $Es_2 = Es = 200000.00$

$y_v = 0.0012967$

$sh_v = 0.0044814$

$ft_v = 373.4504$

$fy_v = 311.2087$

$suv = 0.00512$

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 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 $fsv = fs = 311.2087$

with $Esv = Es = 200000.00$

$1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.09037478$

$2 = Asl,com / (b * d) * (fs_2 / fc) = 0.09037478$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.04381808$

and confined core properties:

$b = 340.00$

$d = 327.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 24.23468$

$cc (5A.5, TBDY) = 0.00411734$

$c =$ confinement factor = 1.21173

$1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.1160777$

$2 = Asl,com / (b * d) * (fs_2 / fc) = 0.1160777$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.0562801$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u(4.9) = 0.2021744$$

$$M_u = M_{Rc}(4.14) = 1.1045E+008$$

$$u = s_u(4.1) = 1.7976030E-005$$

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:

$$u = 1.7976030E-005$$

$$M_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$w_e((5.4c), TBDY) = a_{se} * s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$f_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se}((5.4d), TBDY) = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$$

$$p_{sh,x}(5.4d) = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

psh,y (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 24.23468

$$cc \text{ (5A.5, TBDY)} = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = \text{Asl,ten}/(b*d)*(fs1/fc) = 0.1160777$$

$$2 = \text{Asl,com}/(b*d)*(fs2/fc) = 0.1160777$$

$$v = \text{Asl,mid}/(b*d)*(fsv/fc) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$su \text{ (4.9)} = 0.2021744$$

$$Mu = MRc \text{ (4.14)} = 1.1045E+008$$

$$u = su \text{ (4.1)} = 1.7976030E-005$$

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:

$$u = 1.7976030E-005$$

$$Mu = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$fc = 20.00$$

$$co \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.018$$

$$w_e \text{ ((5.4c), TBDY)} = ase * sh_{,min} * fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.14357935$$

where $f = af * pf * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$fx = 0.11712639$$

$$af = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ff,e = 804.2922$$

$$fy = 0.11712639$$

$$af = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ff,e = 804.2922$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } tf = NL * t * \text{Cos}(b1) = 1.016$$

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = 0.24250288$$

$$bo = 340.00$$

$$ho = 340.00$$

bi2 = 462400.00
psh,min = Min(psh,x , psh,y) = 0.00392699

psh,x (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

psh,y (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
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 = 311.2087

with Esv = Es = 200000.00

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.09037478$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09037478$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.04381808$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 24.23468$$

$$c_c (5A.5, TBDY) = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1160777$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1160777$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.2021744$$

$$\mu_u = M R_c (4.14) = 1.1045E+008$$

$$u = s_u (4.1) = 1.7976030E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 524051.339$

Calculation of Shear Strength at edge 1, $V_{r1} = 524051.339$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$

$$V_{Col0} = 524051.339$$

$k_{nl} = 1$ (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)

$$f'_c = 20.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/d = 2.00$$

$$\mu_u = 4.6307395E-012$$

$$V_u = 4.2515079E-047$$

$$d = 0.8 * h = 320.00$$

$$N_u = 5926.932$$

$$A_g = 160000.00$$

From (11.5.4.8), ACI 318-14: $V_s = 223402.144$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

V_s is multiplied by $Col = 1.00$

$$s/d = 0.3125$$

$$V_f ((11-3)-(11.4), ACI 440) = 188111.148$$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|), \text{ with:}$$

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 357.00$$

$$f_{fe} ((11-5), ACI 440) = 259.312$$

$$E_f = 64828.00$$

$f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 380269.701$
 $b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 524051.339$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l * V_{Col0}$
 $V_{Col0} = 524051.339$
 $k_n l = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

 $= 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / V d = 2.00$

$\mu_u = 4.6307395E-012$

$V_u = 4.2515079E-047$

$d = 0.8 * h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = 223402.144$

$A_v = 157079.633$

$f_y = 444.4444$

$s = 100.00$

V_s is multiplied by $Col = 1.00$

$s / d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 188111.148

$f = 0.95$, for fully-wrapped sections

$w_f / s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 380269.701$

$b_w = 400.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\phi = 0.95$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$
Section Height, $H = 400.00$
Section Width, $W = 400.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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, $M = -1.6233527E-010$
Shear Force, $V_2 = 5652.966$
Shear Force, $V_3 = 1.9223267E-013$
Axial Force, $F = -5924.669$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten} = 829.3805$
-Compression: $A_{st,com} = 829.3805$
-Middle: $A_{st,mid} = 402.1239$
Mean Diameter of Tension Reinforcement, $D_{bL} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.04262022$
 $u = y + p = 0.04486339$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00286339$ ((4.29), Biskinis Phd)
 $M_y = 7.7038E+007$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.3452E+013$
factor = 0.30
 $A_g = 160000.00$
 $f_c' = 20.00$
 $N = 5924.669$
 $E_c * I_g = 4.4841E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.8497516E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b/l_d)^{2/3}) = 248.9669$

$d = 357.00$
 $y = 0.28100816$
 $A = 0.01459861$
 $B = 0.00825178$
 with $pt = 0.00580799$
 $pc = 0.00580799$
 $pv = 0.00281599$
 $N = 5924.669$
 $b = 400.00$
 $\rho = 0.12044818$
 $y_{comp} = 1.8620196E-005$
 with $f_c^* (12.3, (ACI 440)) = 21.65599$
 $f_c = 20.00$
 $f_l = 0.93147527$
 $b = 400.00$
 $h = 400.00$
 $Ag = 160000.00$
 From (12.9), ACI 440: $k_a = 0.56708553$
 $g = pt + pc + pv = 0.01443197$
 $rc = 40.00$
 $A_e/A_c = 0.56708553$
 Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.2789878$
 $A = 0.01432011$
 $B = 0.00808514$
 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: $\rho = 0.042$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
 shear control ratio $V_y E / V_{col} E = 0.14050197$

$d = 357.00$

$s = 0.00$

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$

$A_v = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$b_w = 400.00$

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.

$N_{UD} = 5924.669$

$Ag = 160000.00$

$f_{cE} = 20.00$

$f_{yE} = f_{yI} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.01443197$

$b = 400.00$

$d = 357.00$

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 15

column C1, Floor 1

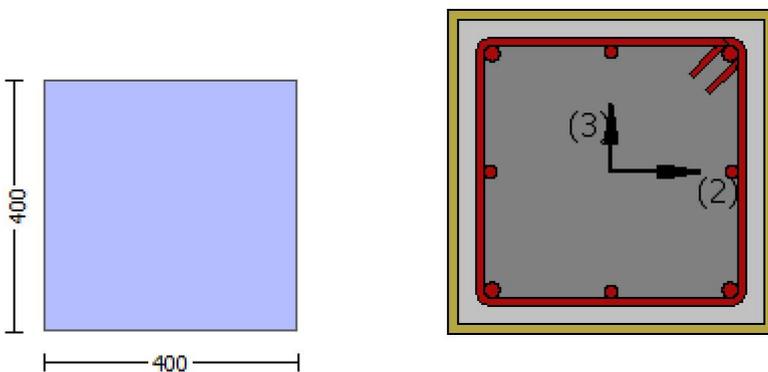
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 0.95$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$

#####

Section Height, $H = 400.00$

Section Width, $W = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $ε_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = 7.3941089E-010$

Shear Force, $V_a = -1.9223267E-013$

EDGE -B-

Bending Moment, $M_b = -1.6233527E-010$

Shear Force, $V_b = 1.9223267E-013$

BOTH EDGES

Axial Force, $F = -5924.669$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 829.3805$

-Compression: $A_{sl,com} = 829.3805$

-Middle: $A_{sl,mid} = 402.1239$

Mean Diameter of Tension Reinforcement, $D_{bL,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = V_n = 445406.907$

$V_n ((10.3), ASCE 41-17) = knl * V_{Col} = 468849.376$

$V_{Col} = 468849.376$

$knl = 1.00$

$displacement_ductility_demand = 0.00$

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)

$M / Vd = 2.00$

$M_u = 1.6233527E-010$

$V_u = 1.9223267E-013$

$d = 0.8 * h = 320.00$

$N_u = 5924.669$

$A_g = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = 201061.93$

$A_v = 157079.633$

$f_y = 400.00$

$s = 100.00$

V_s is multiplied by $Col = 1.00$

$s/d = 0.3125$

$V_f ((11-3)-(11.4), ACI 440) = 188111.148$

$f = 0.95$, for fully-wrapped sections

$w_f / s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation θ , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = 45^\circ$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 340123.561$

$b_w = 400.00$

displacement ductility demand is calculated as δ / y

- Calculation of δ / y for END B -

for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 1.1274962E-020$

$y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00286339$ ((4.29), Biskinis Phd)

$M_y = 7.7038E+007$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00

From table 10.5, ASCE 41_17: $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 1.3452E+013$

factor = 0.30

$A_g = 160000.00$

$f_c' = 20.00$

$N = 5924.669$

$E_c \cdot I_g = 4.4841E+013$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$

$y_{\text{ten}} = 4.8497516E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 248.9669$

$d = 357.00$

$y = 0.28100816$

$A = 0.01459861$

$B = 0.00825178$

with $p_t = 0.00580799$

$p_c = 0.00580799$

$p_v = 0.00281599$

$N = 5924.669$

$b = 400.00$

$\alpha = 0.12044818$

$y_{\text{comp}} = 1.8620196E-005$

with f_c^* (12.3, (ACI 440)) = 21.65599

$f_c = 20.00$

$f_l = 0.93147527$

$b = 400.00$

$h = 400.00$

$A_g = 160000.00$

From (12.9), ACI 440: $k_a = 0.56708553$

$g = p_t + p_c + p_v = 0.01443197$

$r_c = 40.00$

$A_e / A_c = 0.56708553$

Effective FRP thickness, $t_f = N_L \cdot t \cdot \text{Cos}(\theta) = 1.016$

effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 21019.039$

$y = 0.2789878$

A = 0.01432011
B = 0.00808514
with Es = 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: (b)

Calculation No. 16

column C1, Floor 1

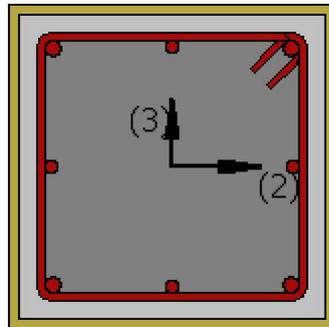
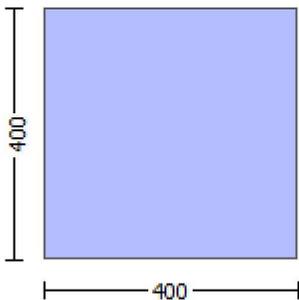
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 0.95$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

Section Height, $H = 400.00$

Section Width, $W = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.21173

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $V_a = -6.9434686E-031$

EDGE -B-

Shear Force, $V_b = 6.9434686E-031$

BOTH EDGES

Axial Force, $F = -5926.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t, \text{ten}} = 829.3805$

-Compression: $As_{c, \text{com}} = 829.3805$

-Middle: $As_{c, \text{mid}} = 402.1239$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.14050197$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 73630.246$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.1045E+008$

$M_{u1+} = 1.1045E+008$, 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

$M_{u1-} = 1.1045E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.1045E+008$

$M_{u2+} = 1.1045E+008$, 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

$M_{u2-} = 1.1045E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of M_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.7976030E-005$$

$$Mu = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.018$$

$$\phi_{we} \text{ ((5.4c), TBDY)} = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.14357935$$

where $\phi = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$\phi_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$p_{sh, \min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$$

$$p_{sh,x} \text{ (5.4d)} = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$ft_1 = 373.4504$$

$$fy_1 = 311.2087$$

$$su_1 = 0.00512$$

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.

$$\text{with } f_{s1} = f_s = 311.2087$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.0012967$$

$$sh_2 = 0.0044814$$

$$ft_2 = 373.4504$$

$$fy_2 = 311.2087$$

$$s_u2 = 0.00512$$

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.

$$\text{with } f_{s2} = f_s = 311.2087$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

$$s_{uv} = 0.00512$$

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.

$$\text{with } f_{sv} = f_s = 311.2087$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.09037478$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.09037478$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.04381808$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 24.23468$$

$$cc (5A.5, TBDY) = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.1160777$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.1160777$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

---->

$$s_u (4.9) = 0.2021744$$

$$\mu_u = M_{Rc} (4.14) = 1.1045E+008$$

$$u = s_u (4.1) = 1.7976030E-005$$

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:

$$\mu_u = 1.7976030E-005$$

$$\mu_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$\text{we ((5.4c), TBDY) } = a_{se} * \text{sh}_{, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$f_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$p_{sh, \min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$$

$$p_{sh,x} \text{ (5.4d)} = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00411734$

$$c = \text{confinement factor} = 1.21173$$

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$ft_1 = 373.4504$$

$$fy_1 = 311.2087$$

$$su_1 = 0.00512$$

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

$$l_0/l_{ou,min} = l_b/l_d = 0.30$$

$$su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs_1 = fs = 311.2087$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.0012967$$

$$sh_2 = 0.0044814$$

$$ft_2 = 373.4504$$

$$fy_2 = 311.2087$$

$$su_2 = 0.00512$$

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

$$l_0/l_{ou,min} = l_b/l_{b,min} = 0.30$$

$$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$$

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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 311.2087$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

$$suv = 0.00512$$

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

$$l_0/l_{ou,min} = l_b/l_d = 0.30$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $fsy_v = fsv/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 311.2087$$

$$\text{with } Es_v = Es = 200000.00$$

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.09037478$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.09037478$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.04381808$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 24.23468$$

$$cc (5A.5, TBDY) = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.1160777$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.1160777$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_s, y_2$ - LHS eq.(4.5) is satisfied

--->

$s_u(4.9) = 0.2021744$

$M_u = M_{Rc}(4.14) = 1.1045E+008$

$u = s_u(4.1) = 1.7976030E-005$

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:

$u = 1.7976030E-005$

$M_u = 1.1045E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00207526$

$N = 5926.932$

$f_c = 20.00$

$\alpha(5A.5, TBDY) = 0.002$

Final value of α : $\alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.018$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\alpha = 0.018$

$\omega(5.4c, TBDY) = \alpha * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$

where $f = \alpha * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.11712639$

$\alpha_f = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $f_{fe} = 804.2922$

 $f_y = 0.11712639$

$\alpha_f = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $f_{fe} = 804.2922$

 $R = 40.00$

Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$\alpha_{se}(5.4d, TBDY) = 0.24250288$

$b_o = 340.00$

$h_o = 340.00$

$b_{i2} = 462400.00$

$p_{sh, \min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$

 $p_{sh,x}(5.4d) = 0.00392699$

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 400.00$

psh,y (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00
d = 327.00
d' = 13.00

fcc (5A.2, TBDY) = 24.23468
cc (5A.5, TBDY) = 0.00411734
c = confinement factor = 1.21173
1 = $Asl,ten/(b*d)*(fs1/fc)$ = 0.1160777
2 = $Asl,com/(b*d)*(fs2/fc)$ = 0.1160777
v = $Asl,mid/(b*d)*(fsv/fc)$ = 0.0562801

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->
v < vs,y2 - LHS eq.(4.5) is satisfied

--->
su (4.9) = 0.2021744
Mu = MRc (4.14) = 1.1045E+008
u = su (4.1) = 1.7976030E-005

Calculation of ratio lb/l_d

Inadequate Lap Length with lb/l_d = 0.30

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.7976030E-005
Mu = 1.1045E+008

with full section properties:

b = 400.00
d = 357.00
d' = 43.00
v = 0.00207526
N = 5926.932
fc = 20.00
co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = shear_factor * Max(cu, cc) = 0.018$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.018

$we ((5.4c), TBDY) = ase * sh,min*fywe/fce + Min(fx, fy) = 0.14357935$

where $f = af*pf*ffe/fce$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.11712639

af = 0.57333333

b = 400.00

h = 400.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

bw = 400.00

effective stress from (A.35), $ff,e = 804.2922$

fy = 0.11712639

af = 0.57333333

b = 400.00

h = 400.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

bw = 400.00

effective stress from (A.35), $ff,e = 804.2922$

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) = 0.24250288

bo = 340.00

ho = 340.00
bi2 = 462400.00
psh,min = Min(psh,x , psh,y) = 0.00392699

psh,x (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

psh,y (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173
y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
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 = 311.2087

with $E_{sv} = E_s = 200000.00$

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.09037478$$

$$2 = A_{s1,com}/(b*d)*(f_{s2}/f_c) = 0.09037478$$

$$v = A_{s1,mid}/(b*d)*(f_{sv}/f_c) = 0.04381808$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 24.23468$$

$$c_c (5A.5, TBDY) = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.1160777$$

$$2 = A_{s1,com}/(b*d)*(f_{s2}/f_c) = 0.1160777$$

$$v = A_{s1,mid}/(b*d)*(f_{sv}/f_c) = 0.0562801$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.2021744$$

$$\mu_u = M_{Rc} (4.14) = 1.1045E+008$$

$$u = s_u (4.1) = 1.7976030E-005$$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 524051.339$

Calculation of Shear Strength at edge 1, $V_{r1} = 524051.339$

$$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$$

$$V_{Col0} = 524051.339$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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)

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/d = 2.00$$

$$\mu_u = 1.8671199E-011$$

$$V_u = 6.9434686E-031$$

$$d = 0.8 * h = 320.00$$

$$N_u = 5926.932$$

$$A_g = 160000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 223402.144$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

$$V_s \text{ is multiplied by } C_{ol} = 1.00$$

$$s/d = 0.3125$$

$$V_f ((11-3)-(11.4), ACI 440) = 188111.148$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$$w_f/s_f = 1 \text{ (FRP strips adjacent to one another).}$$

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.

$$\text{orientation 1: } \theta = b1 + 90^\circ = 90.00$$

$$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = N_L * t / N_{oDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 357.00$$

$$f_{fe} ((11-5), ACI 440) = 259.312$$

$E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 380269.701$
 $bw = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 524051.339$
 $V_{r2} = V_{CoI} ((10.3), ASCE 41-17) = knl * V_{CoI0}$
 $V_{CoI0} = 524051.339$
 $knl = 1$ (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)
 $M / Vd = 2.00$
 $\mu_u = 1.8671199E-011$
 $V_u = 6.9434686E-031$
 $d = 0.8 * h = 320.00$
 $N_u = 5926.932$
 $A_g = 160000.00$
From (11.5.4.8), ACI 318-14: $V_s = 223402.144$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$

V_s is multiplied by $Col = 1.00$

$s/d = 0.3125$

$V_f ((11-3)-(11.4), ACI 440) = 188111.148$

$f = 0.95$, for fully-wrapped sections

$w_f / s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $tf1 = NL * t / NoDir = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

$ff_e ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 380269.701$

$bw = 400.00$

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, $\phi = 0.95$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

Section Height, $H = 400.00$

Section Width, $W = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.21173

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $V_a = 4.2515079E-047$

EDGE -B-

Shear Force, $V_b = -4.2515079E-047$

BOTH EDGES

Axial Force, $F = -5926.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl} = 0.00$

-Compression: $A_{slc} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl, \text{ten}} = 829.3805$

-Compression: $A_{sl, \text{com}} = 829.3805$

-Middle: $A_{sl, \text{mid}} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.14050197$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 73630.246$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.1045E+008$

$M_{u1+} = 1.1045E+008$, 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

$M_{u1-} = 1.1045E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.1045E+008$

$M_{u2+} = 1.1045E+008$, 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

$M_{u2-} = 1.1045E+008$, 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 κ_u according to 4.1, Biskinis/Fardis 2013:

$$\kappa_u = 1.7976030E-005$$

$$\mu = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

$$\kappa_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \kappa_u: \kappa_u^* = \text{shear_factor} * \text{Max}(\kappa_u, \kappa_o) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \kappa_u = 0.018$$

$$\omega_e \text{ ((5.4c), TBDY)} = a_{se} * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$f_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 804.2922$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$$

$$p_{sh,x} \text{ (5.4d)} = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \kappa_c = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$f_{t1} = 373.4504$$

$$f_{y1} = 311.2087$$

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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 24.23468

cc (5A.5, TBDY) = 0.00411734

c = confinement factor = 1.21173

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1160777

2 = Asl,com/(b*d)*(fs2/fc) = 0.1160777

v = Asl,mid/(b*d)*(fsv/fc) = 0.0562801

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.2021744

Mu = MRc (4.14) = 1.1045E+008

u = su (4.1) = 1.7976030E-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:

$\mu_u = 1.7976030E-005$

$\mu_{u1} = 1.1045E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00207526$

$N = 5926.932$

$f_c = 20.00$

α_{co} (5A.5, TBDY) = 0.002

Final value of μ_{cu} : $\mu_{cu}^* = \text{shear_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.018$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_{cu} = 0.018$

μ_{we} ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$

where $f = \alpha_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.11712639$

$\alpha_f = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 804.2922$

$f_y = 0.11712639$

$\alpha_f = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 804.2922$

$R = 40.00$

Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{u,f} = 0.015$

α_{se} ((5.4d), TBDY) = 0.24250288

$b_o = 340.00$

$h_o = 340.00$

$b_{i2} = 462400.00$

$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$

$p_{sh,x}$ (5.4d) = 0.00392699

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirups, $n_s = 2.00$

$b_k = 400.00$

$p_{sh,y}$ (5.4d) = 0.00392699

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirups, $n_s = 2.00$

$b_k = 400.00$

$s = 100.00$

$$fywe = 555.5556$$

$$fce = 20.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00411734$

$$c = \text{confinement factor} = 1.21173$$

$$y1 = 0.0012967$$

$$sh1 = 0.0044814$$

$$ft1 = 373.4504$$

$$fy1 = 311.2087$$

$$su1 = 0.00512$$

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.

$$\text{with } fs1 = fs = 311.2087$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.0012967$$

$$sh2 = 0.0044814$$

$$ft2 = 373.4504$$

$$fy2 = 311.2087$$

$$su2 = 0.00512$$

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.

$$\text{with } fs2 = fs = 311.2087$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.0012967$$

$$shv = 0.0044814$$

$$ftv = 373.4504$$

$$fyv = 311.2087$$

$$suv = 0.00512$$

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.

$$\text{with } fsv = fs = 311.2087$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.09037478$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.09037478$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.04381808$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 24.23468$$

$$cc (5A.5, TBDY) = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.1160777$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.1160777$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.0562801$$

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) = 0.2021744

$M_u = M_{Rc}$ (4.14) = 1.1045E+008

$u = s_u$ (4.1) = 1.7976030E-005

Calculation of ratio I_b/I_d

Inadequate Lap Length with $I_b/I_d = 0.30$

Calculation of M_{u2+}

Calculation of ultimate curvature κ_u according to 4.1, Biskinis/Fardis 2013:

$\kappa_u = 1.7976030E-005$

$M_u = 1.1045E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00207526$

$N = 5926.932$

$f_c = 20.00$

α (5A.5, TBDY) = 0.002

Final value of κ_u : $\kappa_u^* = \text{shear_factor} * \text{Max}(\kappa_u, \kappa_c) = 0.018$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\kappa_u = 0.018$

ω_e ((5.4c), TBDY) = $\alpha s_e * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$

where $f = \alpha_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.11712639$

$\alpha_f = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A4.4.3(6), $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 804.2922$

$f_y = 0.11712639$

$\alpha_f = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A4.4.3(6), $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 804.2922$

$R = 40.00$

Effective FRP thickness, $t_f = N L^* t \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

αs_e ((5.4d), TBDY) = 0.24250288

$b_o = 340.00$

$h_o = 340.00$

$b_i^2 = 462400.00$

$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$

$p_{sh,x}$ (5.4d) = 0.00392699

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirups, $n_s = 2.00$

bk = 400.00

psh,y (5.4d) = 0.00392699

Ash = Astir*ns = 78.53982

No stirups, ns = 2.00

bk = 400.00

s = 100.00

fywe = 555.5556

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00411734

c = confinement factor = 1.21173

y1 = 0.0012967

sh1 = 0.0044814

ft1 = 373.4504

fy1 = 311.2087

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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

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 = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09037478

2 = Asl,com/(b*d)*(fs2/fc) = 0.09037478

v = Asl,mid/(b*d)*(fsv/fc) = 0.04381808

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00
fcc (5A.2, TBDY) = 24.23468
cc (5A.5, TBDY) = 0.00411734
c = confinement factor = 1.21173
1 = $Asl,ten/(b*d)*(fs1/fc) = 0.1160777$
2 = $Asl,com/(b*d)*(fs2/fc) = 0.1160777$
v = $Asl,mid/(b*d)*(fsv/fc) = 0.0562801$
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->
v < vs,y2 - LHS eq.(4.5) is satisfied

--->
su (4.9) = 0.2021744
Mu = MRc (4.14) = 1.1045E+008
u = su (4.1) = 1.7976030E-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 = 1.7976030E-005
Mu = 1.1045E+008

with full section properties:

b = 400.00
d = 357.00
d' = 43.00
v = 0.00207526
N = 5926.932
fc = 20.00
co (5A.5, TBDY) = 0.002
Final value of cu: $cu^* = shear_factor * Max(cu, cc) = 0.018$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $cu = 0.018$
 $we ((5.4c), TBDY) = ase * sh,min*fywe/fce + Min(fx, fy) = 0.14357935$
where $f = af*pf*ffe/fce$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.11712639
af = 0.57333333
b = 400.00
h = 400.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$
bw = 400.00
effective stress from (A.35), $ffe = 804.2922$

fy = 0.11712639
af = 0.57333333
b = 400.00
h = 400.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$
bw = 400.00
effective stress from (A.35), $ffe = 804.2922$

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) = 0.24250288

bo = 340.00
ho = 340.00
bi2 = 462400.00
psh,min = Min(psh,x , psh,y) = 0.00392699

psh,x (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

psh,y (5.4d) = 0.00392699
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 400.00

s = 100.00
fywe = 555.5556
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00411734
c = confinement factor = 1.21173

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
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/lb)^ 2/3), from 10.3.5, ASCE41-17.

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
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.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 311.2087$
with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.09037478$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09037478$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.04381808$

and confined core properties:

$b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 24.23468$
 $cc (5A.5, TBDY) = 0.00411734$
 $c = \text{confinement factor} = 1.21173$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1160777$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1160777$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0562801$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->
 $su (4.9) = 0.2021744$
 $\mu_u = MR_c (4.14) = 1.1045E+008$
 $u = su (4.1) = 1.7976030E-005$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 524051.339$

Calculation of Shear Strength at edge 1, $V_{r1} = 524051.339$
 $V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$
 $V_{Col0} = 524051.339$
 $k_{nl} = 1$ (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)

$M/Vd = 2.00$

$\mu_u = 4.6307395E-012$

$\mu_v = 4.2515079E-047$

$d = 0.8 * h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = 223402.144$

$A_v = 157079.633$

$f_y = 444.4444$

$s = 100.00$

V_s is multiplied by $Col = 1.00$

$s/d = 0.3125$

$V_f ((11-3)-(11.4), ACI 440) = 188111.148$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = 45^\circ$ and $a = 90^\circ$

$V_f = \text{Min}(|V_f(45, 90)|, |V_f(-45, 90)|)$, with:

total thickness per orientation, $t_{f1} = NL * t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

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 <= 380269.701
bw = 400.00

Calculation of Shear Strength at edge 2, Vr2 = 524051.339
Vr2 = VCol ((10.3), ASCE 41-17) = knl*VCol0
VCol0 = 524051.339
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 = 4.6307395E-012
Vu = 4.2515079E-047
d = 0.8*h = 320.00
Nu = 5926.932
Ag = 160000.00
From (11.5.4.8), ACI 318-14: Vs = 223402.144
Av = 157079.633
fy = 444.4444
s = 100.00

Vs is multiplied by Col = 1.00
s/d = 0.3125

Vf ((11-3)-(11.4), ACI 440) = 188111.148
f = 0.95, for fully-wrapped sections

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3) sin + 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) = 357.00

ffe ((11-5), ACI 440) = 259.312

Ef = 64828.00

fe = 0.004, from (11.6a), ACI 440

with fu = 0.01

From (11-11), ACI 440: Vs + Vf <= 380269.701

bw = 400.00

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: rcrcs

Constant Properties

Knowledge Factor, = 0.95

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Primary Member: Concrete Strength, fc = fcm = 20.00

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$
Section Height, $H = 400.00$
Section Width, $W = 400.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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, $M = 0.16676193$
Shear Force, $V_2 = 5652.966$
Shear Force, $V_3 = 1.9223267E-013$
Axial Force, $F = -5924.669$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten} = 829.3805$
-Compression: $A_{st,com} = 829.3805$
-Middle: $A_{st,mid} = 402.1239$
Mean Diameter of Tension Reinforcement, $DbL = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.04044404$
 $u = y + p = 0.04257268$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00057268$ ((4.29), Biskinis Phd)
 $M_y = 7.7038E+007$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.3452E+013$
factor = 0.30
 $A_g = 160000.00$
 $f_c' = 20.00$
 $N = 5924.669$
 $E_c * I_g = 4.4841E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 4.8497516E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25*f_y*(l_b/l_d)^{2/3}) = 248.9669$
 $d = 357.00$
 $y = 0.28100816$
 $A = 0.01459861$
 $B = 0.00825178$
 with $pt = 0.00580799$
 $pc = 0.00580799$
 $pv = 0.00281599$
 $N = 5924.669$
 $b = 400.00$
 $" = 0.12044818$
 $y_{comp} = 1.8620196E-005$
 with $f_c^* (12.3, (ACI 440)) = 21.65599$
 $f_c = 20.00$
 $fl = 0.93147527$
 $b = 400.00$
 $h = 400.00$
 $Ag = 160000.00$
 From (12.9), ACI 440: $ka = 0.56708553$
 $g = pt + pc + pv = 0.01443197$
 $rc = 40.00$
 $Ae/Ac = 0.56708553$
 Effective FRP thickness, $t_f = NL*t*Cos(b1) = 1.016$
 effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.2789878$
 $A = 0.01432011$
 $B = 0.00808514$
 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: $p = 0.042$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
 shear control ratio $V_yE/V_{ColOE} = 0.14050197$

$d = 357.00$

$s = 0.00$

$t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.00$

$A_v = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$b_w = 400.00$

The term $2*t_f/b_w*(f_{fe}/f_s)$ is implemented to account for FRP contribution

where $f = 2*t_f/b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe}/f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

$NUD = 5924.669$

$Ag = 160000.00$

$f_{cE} = 20.00$

$f_{yE} = f_{yI} = 0.00$

$pl = \text{Area_Tot_Long_Rein}/(b*d) = 0.01443197$

$b = 400.00$

$d = 357.00$

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (b)

