

# Detailed Member Calculations

**Units: N&mm**

**Regulation: ASCE 41-17**

## Calculation No. 1

column C1, Floor 1

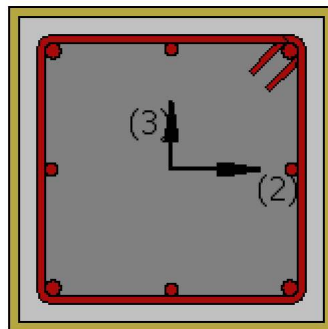
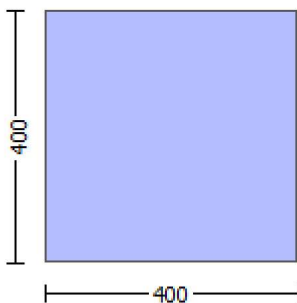
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $VR_d$

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  $\gamma$  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  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Inadequate Lap Length with  $l_o/l_{ou,min} = l_b/l_d = 0.30$   
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $e_{fu} = 0.01$   
 Number of directions,  $NoDir = 1$   
 Fiber orientations,  $bi: 0.00^\circ$   
 Number of layers,  $NL = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

EDGE -A-  
 Bending Moment,  $M_a = -1.3563E+007$   
 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:  $As_t = 829.3805$   
   -Compression:  $As_c = 1231.504$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $As_{t,ten} = 829.3805$   
   -Compression:  $As_{l,com} = 829.3805$   
   -Middle:  $As_{l,mid} = 402.1239$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = *V_n = 384262.188$   
 $V_n ((10.3), ASCE 41-17) = knl * V_{CoI} = 404486.513$   
 $V_{CoI} = 404486.513$   
 $knl = 1.00$   
 $displacement\_ductility\_demand = 0.04959002$

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

$\gamma = 1$  (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:  $V_s = 201061.93$   
 $Av = 157079.633$   
 $f_y = 400.00$   
 $s = 100.00$   
 $V_s$  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  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL \cdot t / NoDir = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 357.00  
 $ffe ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 340123.561$   
 $bw = 400.00$

displacement ductility demand is calculated as  $\delta / y$

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

From analysis, chord rotation  $\theta = 0.0002841$   
 $y = (My \cdot L_s / 3) / Eleff = 0.00572891$  ((4.29), Biskinis Phd))  
 $My = 7.7038E+007$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 3001.112  
 From table 10.5, ASCE 41-17:  $Eleff = factor \cdot Ec \cdot I_g = 1.3452E+013$   
 $factor = 0.30$   
 $Ag = 160000.00$   
 $fc' = 20.00$   
 $N = 5925.123$   
 $Ec \cdot I_g = 4.4841E+013$

Calculation of Yielding Moment  $My$

Calculation of  $\delta$  and  $My$  according to Annex 7 -

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

$f_l = 0.93147527$   
 $b = 400.00$   
 $h = 400.00$   
 $A_g = 160000.00$   
 From (12.9), ACI 440:  $k_a = 0.56708553$   
 $g = p_t + p_c + p_v = 0.01443197$   
 $r_c = 40.00$   
 $A_e/A_c = 0.56708553$   
 Effective FRP thickness,  $t_f = N_L * t * \cos(\theta_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 21019.039$   
 $\gamma = 0.27898785$   
 $A = 0.0143201$   
 $B = 0.00808514$   
 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

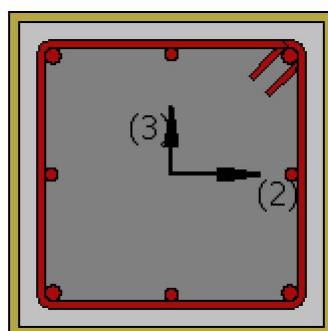
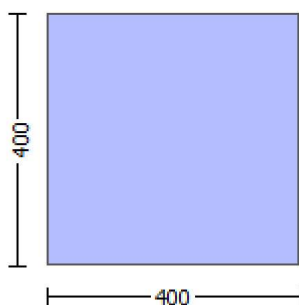
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

Edge: Start

Local Axis: (2)



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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
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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,  $ef_u = 0.01$ 
Number of directions,  $NoDir = 1$ 
Fiber orientations,  $bi: 0.00^\circ$ 
Number of layers,  $NL = 1$ 
Radius of rounding corners,  $R = 40.00$ 
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Stepwise Properties
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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:  $As_{l,mid} = 402.1239$ 
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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

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

$M_{u1+} = 1.1045E+008$ , 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  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 1.7976030E-005$$

$$M_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

The Shear\_factor is considered equal to 1 (pure moment strength)

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

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

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

$$\phi_{fx} = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$\phi_{fy} = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$\phi_{u,f} = 0.015$$

$$a_{se} ((5.4d), \text{TB DY}) = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

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

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

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

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

$$b_k = 400.00$$

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

Ash = Astir\*ns = 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

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

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

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

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

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$\mu_u(4.9) = 0.2021744$

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

$u = \mu_u(4.1) = 1.7976030E-005$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{u1}$ -

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.7976030E-005$

$\mu_u = 1.1045E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00207526$

$N = 5926.932$

$f_c = 20.00$

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

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

The Shear\_factor is considered equal to 1 (pure moment strength)

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

$\mu_{we}((5.4c), TBDY) = a_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$

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

$f_x = 0.11712639$

$a_f = 0.57333333$

$b = 400.00$

$h = 400.00$

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

$bw = 400.00$

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

$f_y = 0.11712639$

$a_f = 0.57333333$

$b = 400.00$

$h = 400.00$

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

$bw = 400.00$

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

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

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

$b_o = 340.00$

$h_o = 340.00$

$b_{i2} = 462400.00$



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

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

$$Ash = Astir*ns = 78.53982$$

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

$$bk = 400.00$$

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

$$Ash = Astir*ns = 78.53982$$

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

$$bk = 400.00$$

$$s = 100.00$$

$$fywe = 555.5556$$

$$fce = 20.00$$

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

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

$$y1 = 0.0012967$$

$$sh1 = 0.0044814$$

$$ft1 = 373.4504$$

$$fy1 = 311.2087$$

$$su1 = 0.00512$$

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

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

$$su1 = 0.4*esu1\_nominal ((5.5), \text{TBDY}) = 0.032$$

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

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

$$su2 = 0.4*esu2\_nominal ((5.5), \text{TBDY}) = 0.032$$

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

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

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

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.

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

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

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

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

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

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  $I_b/I_d$

Inadequate Lap Length with  $I_b/I_d = 0.30$

Calculation of  $\mu_{u2+}$

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.7976030E-005$$

$$\mu_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

The Shear\_factor is considered equal to 1 (pure moment strength)

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

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

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

$$f_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$f_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$R = 40.00$$

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

$f_u, f = 1055.00$

$E_f = 64828.00$

$u, f = 0.015$

$a_s((5.4d), TBDY) = 0.24250288$

$b_o = 340.00$

$h_o = 340.00$

$b_{i2} = 462400.00$

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

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

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

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  $((5.4s), TBDY)$ , 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

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

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

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

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

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , 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

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

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

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

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

$y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , 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

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

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

From table 5A.1, TBDY:  $\varepsilon_{suv\_nominal} = 0.08$ ,  
 considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $\varepsilon_{suv\_nominal}$  and  $\gamma_v$ ,  $\gamma_{shv}$ ,  $\gamma_{ftv}$ ,  $\gamma_{fyv}$ , it is considered  
 characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $\gamma_1$ ,  $\gamma_{sh1}$ ,  $\gamma_{ft1}$ ,  $\gamma_{fy1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $f_{sv} = f_s = 311.2087$   
 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:

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

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

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

---->  
 $\mu_u \text{ (4.9)} = 0.2021744$   
 $\mu_u = M_{Rc} \text{ (4.14)} = 1.1045E+008$   
 $u = \mu_u \text{ (4.1)} = 1.7976030E-005$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{u2}$ -

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.7976030E-005$   
 $\mu_u = 1.1045E+008$

with full section properties:

$b = 400.00$   
 $d = 357.00$   
 $d' = 43.00$   
 $v = 0.00207526$   
 $N = 5926.932$   
 $f_c = 20.00$   
 $cc \text{ (5A.5, TBDY)} = 0.002$   
 Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} \cdot \text{Max}(\mu_u, cc) = 0.018$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\mu_u = 0.018$   
 $\mu_{ue} \text{ ((5.4c), TBDY)} = a_{se} \cdot \gamma_{sh,min} \cdot f_{ywe}/f_{ce} + \text{Min}(\mu_u, \mu_{ue}) = 0.14357935$   
 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)

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

$\mu_u = 0.11712639$

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/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  $Min(1,1.25*(lb/lb)^{2/3})$ , 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/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 Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 524051.339$

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

$V_{r1} = V_{Co1} ((10.3), \text{ASCE 41-17}) = knl * V_{Co10}$

$V_{Co10} = 524051.339$

$knl = 1$  (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  $f_c'^{0.5} \leq 8.3 \text{ MPa}$  (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:  $V_s = 223402.144$

$A_v = 157079.633$

$f_y = 444.4444$

$s = 100.00$

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)  $\sin + \cos$  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  $\theta_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$

$$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|), \text{ with:}$$

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

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

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

$$E_f = 64828.00$$

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

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

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

$$b_w = 400.00$$

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

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

$$V_{Col0} = 524051.339$$

$k_{nl} = 1$  (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)

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

$$M/Vd = 2.00$$

$$\mu_u = 1.8671199\text{E-}011$$

$$\nu_u = 6.9434686\text{E-}031$$

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

$$N_u = 5926.932$$

$$A_g = 160000.00$$

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

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

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)  $\sin + \cos$  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  $\theta_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$

$$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|), \text{ with:}$$

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

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

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

$$E_f = 64828.00$$

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

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

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

$$b_w = 400.00$$

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,  $ef_u = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $bi: 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = 4.2515079E-047$

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:  $As_{l,com} = 829.3805$

-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 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  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

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

with full section properties:

$b = 400.00$   
 $d = 357.00$   
 $d' = 43.00$   
 $v = 0.00207526$   
 $N = 5926.932$   
 $f_c = 20.00$   
 $\alpha_1(5A.5, \text{TB DY}) = 0.002$   
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)  
From (5.4b), TB DY:  $\phi_u = 0.018$   
 $\phi_{ue}((5.4c), \text{TB DY}) = \alpha_1 \epsilon_{sh, \min} f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.14357935$   
where  $\phi = \alpha_1 \rho_f f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

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

$\phi_y = 0.11712639$   
 $\alpha_f = 0.57333333$   
 $b = 400.00$   
 $h = 400.00$   
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,  $t_f = NL * t * \text{Cos}(\beta_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $\phi_{u,f} = 0.015$   
 $\alpha_{se}((5.4d), \text{TB DY}) = 0.24250288$   
 $b_o = 340.00$   
 $h_o = 340.00$   
 $b_{i2} = 462400.00$   
 $\rho_{sh, \min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.00392699$   
-----

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

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

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

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

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

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

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - 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  $Mu1$ -

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

$$u = 1.7976030E-005$$

$$Mu = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$fc = 20.00$$

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

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

The Shear\_factor is considered equal to 1 (pure moment strength)

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

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

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

$$fx = 0.11712639$$

$$af = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$fy = 0.11712639$$

$$af = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$R = 40.00$$

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

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase((5.4d), TBDY) = 0.24250288$$

$$bo = 340.00$$

$$ho = 340.00$$

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.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 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 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:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

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

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

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

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

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

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

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su (4.9) = 0.2021744$$

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

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

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{u2+}$

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.7976030E-005$$

$$\mu_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, cc) = 0.018$$

The Shear\_factor is considered equal to 1 (pure moment strength)

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

$$\mu_u \text{ ((5.4c), TBDY)} = a_{se} * \mu_{sh,min} * f_{ywe}/f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.14357935$$

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

$$\mu_{fx} = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$\mu_{fy} = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

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

$p_{sh,x}(5.4d) = 0.00392699$   
 $A_{sh} = A_{stir} * n_s = 78.53982$   
 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  $((5A5), TBDY)$ ,  $TBDY$ :  $c_c = 0.00411734$   
 $c = \text{confinement factor} = 1.21173$

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

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $l_o/l_{ou,min} = l_b/l_d = 0.30$

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

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

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

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\min(1, 1.25 * (l_b/l_d)^{2/3})$ , 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  
 $\text{Shear\_factor} = 1.00$

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

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

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

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

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

with  $fs_2 = fs = 311.2087$   
 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  
 $\text{Shear\_factor} = 1.00$   
 $l_o/l_{ou,min} = l_b/l_d = 0.30$

$\text{su} = 0.4 \cdot \text{esuv\_nominal} ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $\text{esuv\_nominal} = 0.08$ ,  
 considering characteristic value  $\text{fsy} = \text{fsv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $\text{esuv\_nominal}$  and  $\text{yv}$ ,  $\text{shv}$ ,  $\text{ftv}$ ,  $\text{fyv}$ , it is considered  
 characteristic value  $\text{fsy} = \text{fsv}/1.2$ , from table 5.1, TBDY.  
 $\text{y1}$ ,  $\text{sh1}$ ,  $\text{ft1}$ ,  $\text{fy1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $\text{fsv} = \text{fs} = 311.2087$   
 with  $\text{Esv} = \text{Es} = 200000.00$   
 $1 = \text{Asl,ten}/(\text{b} \cdot \text{d}) \cdot (\text{fs1}/\text{fc}) = 0.09037478$   
 $2 = \text{Asl,com}/(\text{b} \cdot \text{d}) \cdot (\text{fs2}/\text{fc}) = 0.09037478$   
 $v = \text{Asl,mid}/(\text{b} \cdot \text{d}) \cdot (\text{fsv}/\text{fc}) = 0.04381808$   
 and confined core properties:  
 $b = 340.00$   
 $d = 327.00$   
 $d' = 13.00$   
 $\text{fcc} (5A.2, \text{TBDY}) = 24.23468$   
 $\text{cc} (5A.5, \text{TBDY}) = 0.00411734$   
 $c = \text{confinement factor} = 1.21173$   
 $1 = \text{Asl,ten}/(\text{b} \cdot \text{d}) \cdot (\text{fs1}/\text{fc}) = 0.1160777$   
 $2 = \text{Asl,com}/(\text{b} \cdot \text{d}) \cdot (\text{fs2}/\text{fc}) = 0.1160777$   
 $v = \text{Asl,mid}/(\text{b} \cdot \text{d}) \cdot (\text{fsv}/\text{fc}) = 0.0562801$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < \text{vs,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $\text{su} (4.9) = 0.2021744$   
 $\text{Mu} = \text{MRc} (4.14) = 1.1045\text{E}+008$   
 $u = \text{su} (4.1) = 1.7976030\text{E}-005$

Calculation of ratio  $\text{lb}/\text{ld}$

Inadequate Lap Length with  $\text{lb}/\text{ld} = 0.30$

Calculation of  $\text{Mu2}$ -

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:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00207526$

$N = 5926.932$

$\text{fc} = 20.00$

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

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

The Shear\_factor is considered equal to 1 (pure moment strength)

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

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

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

$\text{fx} = 0.11712639$

$\text{af} = 0.57333333$

$b = 400.00$

$h = 400.00$

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

$\text{bw} = 400.00$

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

$f_y = 0.11712639$   
 $a_f = 0.57333333$   
 $b = 400.00$   
 $h = 400.00$   
 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,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $a_{se} ((5.4d), TBDY) = 0.24250288$   
 $b_o = 340.00$   
 $h_o = 340.00$   
 $b_{i2} = 462400.00$   
 $p_{sh,min} = \min(p_{sh,x}, p_{sh,y}) = 0.00392699$

$p_{sh,x} (5.4d) = 0.00392699$   
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$   
 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.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  
 $l_o/l_{ou,min} = l_b/l_d = 0.30$   
 $su_1 = 0.4 \cdot esu_{1,nominal} ((5.5), TBDY) = 0.032$   
 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  $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , 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  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$   
 $su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs_2 = fs = 311.2087$   
 with  $Es_2 = Es = 200000.00$   
 $y_v = 0.0012967$



```

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,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  $V_r = \min(V_{r1}, V_{r2}) = 524051.339$

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

$V_{r1} = V_{Co1} ((10.3), \text{ASCE 41-17}) = k_{nl} * V_{Co10}$

$V_{Co10} = 524051.339$

$k_{nl} = 1$  (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)

$M/Vd = 2.00$

$\mu_u = 4.6307395E-012$

$V_u = 4.2515079E-047$

$d = 0.8 * h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

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  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
where  $a$  is the angle of the crack direction (see KANEPE).  
This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
as well as for 2 crack directions,  $= 45^\circ$  and  $= -45^\circ$  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,  $tf_1 = NL \cdot t / NoDir = 1.016$   
 $df_v = d$  (figure 11.2, ACI 440) = 357.00  
 $ffe ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $fe = 0.004$ , from (11.6a), ACI 440  
with  $fu = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 380269.701$   
 $bw = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 524051.339$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{ColO}$   
 $V_{ColO} = 524051.339$   
 $knl = 1$  (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)  
 $fc' = 20.00$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $M_u = 4.6307395E-012$   
 $V_u = 4.2515079E-047$   
 $d = 0.8 \cdot h = 320.00$   
 $N_u = 5926.932$   
 $Ag = 160000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = 223402.144$   
 $A_v = 157079.633$   
 $f_y = 444.4444$   
 $s = 100.00$   
 $V_s$  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  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
where  $a$  is the angle of the crack direction (see KANEPE).  
This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
as well as for 2 crack directions,  $= 45^\circ$  and  $= -45^\circ$  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,  $tf_1 = NL \cdot t / NoDir = 1.016$   
 $df_v = d$  (figure 11.2, ACI 440) = 357.00  
 $ffe ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $fe = 0.004$ , from (11.6a), ACI 440  
with  $fu = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 380269.701$   
 $bw = 400.00$

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: rcrcs

#### 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,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = 5.8739332E-010$

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:  $A_{sl,t} = 829.3805$

-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,  $Db_L = 18.66667$

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

$u = \gamma \cdot u + p = 0.0028634$

- Calculation of  $\gamma$  -

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

$M_y = 7.7038E+007$

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

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

factor = 0.30

$A_g = 160000.00$

$f_c' = 20.00$

$N = 5925.123$

$E_c * I_g = 4.4841E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $\phi_y$  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,  $t_f = N L * t * \cos(b_1) = 1.016$

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  $\phi_p$  -

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

with:

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

shear control ratio  $V_y E / V_{col} O E = 0.14050197$

$d = 357.00$

$s = 0.00$

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

$A_v = 157.0796$ , 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 = 5925.123

Ag = 160000.00

f<sub>cE</sub> = 20.00

f<sub>ytE</sub> = f<sub>ylE</sub> = 0.00

pl = Area\_Tot\_Long\_Rein/(b\*d) = 0.01443197

b = 400.00

d = 357.00

f<sub>cE</sub> = 20.00

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

At local axis: 2

Integration Section: (a)

### Calculation No. 3

column C1, Floor 1

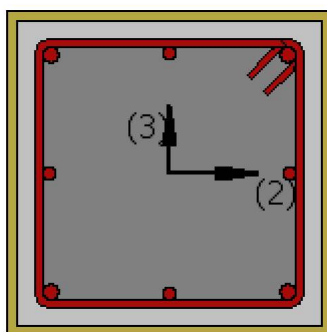
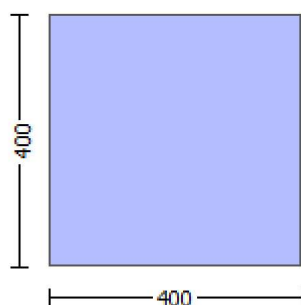
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



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

At local axis: 3

Integration Section: (a)

Section Type: rcrs

Constant Properties

Knowledge Factor,  $\gamma = 0.95$

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  $\gamma$  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,  $bi: 0.00^\circ$   
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:  $As_t = 829.3805$   
-Compression:  $As_c = 1231.504$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten} = 829.3805$   
-Compression:  $As_{l,com} = 829.3805$   
-Middle:  $As_{l,mid} = 402.1239$   
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = *V_n = 445406.993$   
 $V_n$  ((10.3), ASCE 41-17) =  $knI*V_{CoI} = 468849.466$   
 $V_{CoI} = 468849.466$   
 $knI = 1.00$   
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)  
 $M/Vd = 2.00$

$\mu = 5.8739332E-010$   
 $\nu = 1.5368441E-013$   
 $d = 0.8 \cdot h = 320.00$   
 $Nu = 5925.123$   
 $Ag = 160000.00$   
 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  $\text{Col} = 1.00$   
 $s/d = 0.3125$   
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 188111.148$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N L \cdot t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (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:  $V_s + V_f \leq 340123.561$   
 $b_w = 400.00$

displacement ductility demand is calculated as  $\delta / y$

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

From analysis, chord rotation  $\theta = 1.7026306E-020$   
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.0028634$  ((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:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 1.3452E+013$   
 $\text{factor} = 0.30$   
 $Ag = 160000.00$   
 $f_c' = 20.00$   
 $N = 5925.123$   
 $E_c \cdot I_g = 4.4841E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(\delta_{ten}, \delta_{com})$   
 $\delta_{ten} = 4.8497530E-006$   
 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  $p_t = 0.00580799$   
 $p_c = 0.00580799$   
 $p_v = 0.00281599$   
 $N = 5925.123$   
 $b = 400.00$   
 $\theta = 0.12044818$   
 $y_{comp} = 1.8620192E-005$

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:  $k_a = 0.56708553$

$g = p_t + p_c + p_v = 0.01443197$

$rc = 40.00$

$A_e/A_c = 0.56708553$

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  $I_b/I_d$

Inadequate Lap Length with  $I_b/I_d = 0.30$

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

At local axis: 3

Integration Section: (a)

## Calculation No. 4

column C1, Floor 1

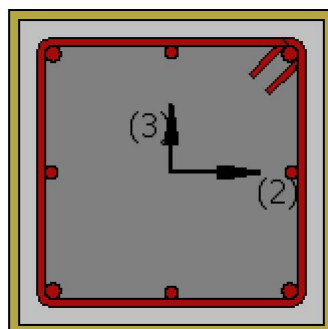
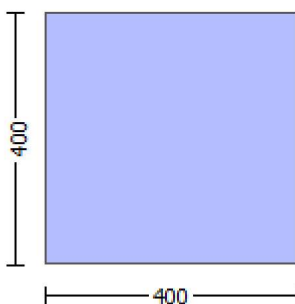
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

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  $135^\circ$ )

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,  $\epsilon_{fu} = 0.01$

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:  $A_{sl,t} = 0.00$

-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 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  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 1.7976030E-005$$

$$M_u = 1.1045E+008$$

-----  
with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

The Shear\_factor is considered equal to 1 (pure moment strength)

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

$$\phi_{ue} \text{ ((5.4c), TBDY)} = a_s e * \phi_{u, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{ux}, \phi_{uy}) = 0.14357935$$

where  $\phi = a_s^2 p_f^2 f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{ux} = 0.11712639$$

$$a_s = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$\phi_{uy} = 0.11712639$$

$$a_s = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t^* \cos(\beta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

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

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

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

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

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

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

$$b_k = 400.00$$

psh,y (5.4d) = 0.00392699  
Ash = Astir\*ns = 78.53982  
No stirrups, 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

$f_{cc}$  (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  
 --->  
 $su$  (4.9) = 0.2021744  
 $\mu_u = M_{Rc}$  (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  $\mu_{u1}$ -

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:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00207526$

$N = 5926.932$

$f_c = 20.00$

$co$  (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:  $cu = 0.018$

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

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

$bw = 400.00$

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

$f_y = 0.11712639$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

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

$bw = 400.00$

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

$R = 40.00$

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/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 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:  
 $b = 340.00$   
 $d = 327.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 24.23468$   
 $cc (5A.5, TBDY) = 0.00411734$   
 $c = \text{confinement factor} = 1.21173$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1160777$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1160777$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0562801$   
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:  $cu = 0.018$   
 $w_e (5.4c, TBDY) = a_s * sh_{min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$   
where  $f = a_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.11712639$   
 $a_f = 0.57333333$   
 $b = 400.00$   
 $h = 400.00$   
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,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $a_{se}((5.4d), TBDY) = 0.24250288$   
 $b_o = 340.00$   
 $h_o = 340.00$   
 $b_{i2} = 462400.00$   
 $p_{sh,min} = \min(p_{sh,x}, p_{sh,y}) = 0.00392699$

$p_{sh,x}(5.4d) = 0.00392699$   
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$   
 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  $((5A5), TBDY)$ ,  $TBDY$ :  $c_c = 0.00411734$   
 $c = \text{confinement factor} = 1.21173$

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

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$

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

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

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

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

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , 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  
 $\text{Shear\_factor} = 1.00$

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

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

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

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

$y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , 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  
 $\text{Shear\_factor} = 1.00$

$l_o/l_{ou,min} = l_b/l_d = 0.30$   
 $suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$   
 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  $yv$ ,  $shv,ftv,fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1,ft1,fy1$ , are also multiplied by  $Min(1,1.25*(l_b/l_d)^{2/3})$ , 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:

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

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  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

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  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.018$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.018$   
 $we ((5.4c), TBDY) = ase * sh,min * fywe/fce + Min(fx, fy) = 0.14357935$   
 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),  $ffe = 804.2922$



$f_y = 0.11712639$   
 $a_f = 0.57333333$   
 $b = 400.00$   
 $h = 400.00$   
 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,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $a_{se} ((5.4d), TBDY) = 0.24250288$   
 $b_o = 340.00$   
 $h_o = 340.00$   
 $b_{i2} = 462400.00$   
 $p_{sh,min} = \min(p_{sh,x}, p_{sh,y}) = 0.00392699$

$p_{sh,x} (5.4d) = 0.00392699$   
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$   
 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.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  
 $l_o/l_{ou,min} = l_b/l_d = 0.30$   
 $su_1 = 0.4 \cdot esu1_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,  
 For calculation of  $esu1_{nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
 characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , 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  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$   
 $su_2 = 0.4 \cdot esu2_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu2_{nominal} = 0.08$ ,  
 For calculation of  $esu2_{nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs_2 = fs = 311.2087$   
 with  $Es_2 = Es = 200000.00$

$y_v = 0.0012967$   
 $sh_v = 0.0044814$   
 $ft_v = 373.4504$   
 $fy_v = 311.2087$   
 $suv = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lo_{u,min} = lb/ld = 0.30$   
 $suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fsv = fs = 311.2087$   
 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) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_{s+} + f * V_f$ '  
 where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)  
 $fc' = 20.00$ , 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:  $V_s = 223402.144$   
 $Av = 157079.633$

$f_y = 444.4444$   
 $s = 100.00$   
 $V_s$  is multiplied by  $\text{Col} = 1.00$   
 $s/d = 0.3125$   
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 188111.148$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
where  $a$  is the angle of the crack direction (see KANEPE).  
This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
as well as for 2 crack directions,  $= 45^\circ$  and  $= -45^\circ$  to take into consideration the cyclic seismic loading.  
orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 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,  $V_{r2} = 524051.339$   
 $V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} \cdot V_{\text{Col}0}$   
 $V_{\text{Col}0} = 524051.339$   
 $k_{nl} = 1$  (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  $f_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $M_u = 1.8671199\text{E-}011$   
 $V_u = 6.9434686\text{E-}031$   
 $d = 0.8 \cdot h = 320.00$   
 $N_u = 5926.932$   
 $A_g = 160000.00$   
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  $\text{Col} = 1.00$   
 $s/d = 0.3125$   
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 188111.148$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
where  $a$  is the angle of the crack direction (see KANEPE).  
This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
as well as for 2 crack directions,  $= 45^\circ$  and  $= -45^\circ$  to take into consideration the cyclic seismic loading.  
orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 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:  $V_s + V_f \leq 380269.701$   
 $b_w = 400.00$

-----  
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  $135^\circ$ )

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,  $ef_u = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $bi: 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = 4.2515079E-047$

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:  $As_{l,com} = 829.3805$

-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

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

$\mu_{1+} = 1.1045\text{E}+008$ , 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

$\mu_{1-} = 1.1045\text{E}+008$ , 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

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

$\mu_{2+} = 1.1045\text{E}+008$ , 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

$\mu_{2-} = 1.1045\text{E}+008$ , 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  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

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

$M_u = 1.1045\text{E}+008$   
-----

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00207526$

$N = 5926.932$

$f_c = 20.00$

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

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)

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

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

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

-----  
 $\phi_{fx} = 0.11712639$

$a_f = 0.57333333$

$b = 400.00$

$h = 400.00$

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

$bw = 400.00$

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

$\phi_{fy} = 0.11712639$

$a_f = 0.57333333$

$b = 400.00$

$h = 400.00$

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

$bw = 400.00$

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

$R = 40.00$

Effective FRP thickness,  $t_f = N L^* t \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,f} = 0.015$

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

$b_o = 340.00$

$h_o = 340.00$

$b_{i2} = 462400.00$

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

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

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

No stirrups,  $n_s = 2.00$

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

$d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 24.23468$   
 $cc (5A.5, TBDY) = 0.00411734$   
 $c = \text{confinement factor} = 1.21173$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1160777$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1160777$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0562801$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

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

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

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $Mu1$ -

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

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

with full section properties:

$b = 400.00$   
 $d = 357.00$   
 $d' = 43.00$   
 $v = 0.00207526$   
 $N = 5926.932$   
 $f_c = 20.00$   
 $co (5A.5, TBDY) = 0.002$   
 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:  $cu = 0.018$   
 $w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$   
 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),  $p_f = 2t_f/bw = 0.00508$   
 $bw = 400.00$   
 effective stress from (A.35),  $f_{fe} = 804.2922$

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

$R = 40.00$   
 Effective FRP thickness,  $t_f = NL * t * \text{Cos}(b1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $a_{se} ((5.4d), TBDY) = 0.24250288$

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,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 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,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 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

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

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  $u$  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:  $cu = 0.018$   
 $w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$   
 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),  $p_f = 2t_f/bw = 0.00508$   
 $bw = 400.00$   
 effective stress from (A.35),  $f_{fe} = 804.2922$

$f_y = 0.11712639$   
 $a_f = 0.57333333$   
 $b = 400.00$   
 $h = 400.00$   
 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,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

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

$b_o = 340.00$

$h_o = 340.00$

$b_{i2} = 462400.00$

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

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

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

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.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

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

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

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

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

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , 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

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

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

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

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

$y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , 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  
 $l_o/l_{ou,min} = l_b/l_d = 0.30$   
 $suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$   
 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  $yv$ ,  $shv,ftv,fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1,ft1,fy1$ , are also multiplied by  $Min(1,1.25*(l_b/l_d)^{2/3})$ , 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:  
 $b = 340.00$   
 $d = 327.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 24.23468$   
 $cc (5A.5, TBDY) = 0.00411734$   
 $c = \text{confinement factor} = 1.21173$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.1160777$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.1160777$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.0562801$   
 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  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

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  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.018$

The Shear\_factor is considered equal to 1 (pure moment strength)

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

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

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),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

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

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

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

$b_o = 340.00$

$h_o = 340.00$

$b_{i2} = 462400.00$

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

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

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

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.A5), TBDY), TBDY:  $c_c = 0.00411734$

$c$  = 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

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

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

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

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

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , 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

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

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

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

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

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

with  $fs_2 = fs = 311.2087$

```

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  $V_r = \min(V_{r1}, V_{r2}) = 524051.339$

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) ' $V_s = A_v * f_y * d / s$ ' 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)

$M/Vd = 2.00$

$\mu_u = 4.6307395E-012$

$V_u = 4.2515079E-047$

$d = 0.8 * h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

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  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 $\ln (11.3) \sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $\theta$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL * t / NoDir = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 357.00  
 $ffe ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 380269.701$   
 $bw = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 524051.339$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{ColO}$   
 $V_{ColO} = 524051.339$   
 $knl = 1$  (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).

$\gamma = 1$  (normal-weight concrete)  
 $f'_c = 20.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $M_u = 4.6307395E-012$   
 $V_u = 4.2515079E-047$   
 $d = 0.8 * h = 320.00$   
 $N_u = 5926.932$   
 $A_g = 160000.00$   
 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  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 $\ln (11.3) \sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $\theta$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL * t / NoDir = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 357.00  
 $ffe ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 380269.701$   
 $bw = 400.00$

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: rcrcs

#### 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  $135^\circ$ )

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,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -1.3563E+007$

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:  $A_{sl,t} = 829.3805$

-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,  $Db_L = 18.66667$

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

$u = \gamma \cdot u + p = 0.00572891$

- Calculation of  $\gamma$  -

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

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

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  $p_t = 0.00580799$   
 $p_c = 0.00580799$   
 $p_v = 0.00281599$   
 $N = 5925.123$   
 $b = 400.00$   
 $" = 0.12044818$   
 $y_{comp} = 1.8620192E-005$   
 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),  $e_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 21019.039$   
 $y = 0.27898785$   
 $A = 0.0143201$   
 $B = 0.00808514$   
 with  $E_s = 200000.00$

Calculation of ratio  $I_b/I_d$

Inadequate Lap Length with  $I_b/I_d = 0.30$

- Calculation of  $p$  -

From table 10-8:  $p = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because  $I_b/I_d \geq 1$   
 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  $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$  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 = 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

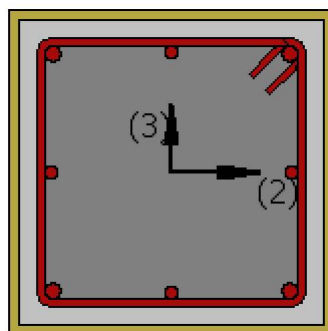
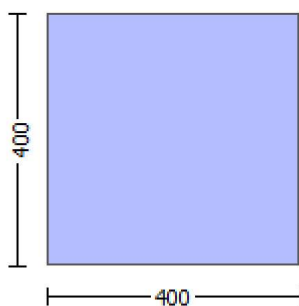
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $VR_d$

Edge: End

Local Axis: (2)



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

At local axis: 2

Integration Section: (b)

Section Type: rcrs

Constant Properties

-----

Knowledge Factor,  $\gamma = 0.95$

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  $\mu$  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,  $bi: 0.00^\circ$

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:  $As_t = 0.00$

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

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

Existing component: From table 7-7, ASCE 41-17: Final Shear Capacity  $V_R = \phi V_n = 445406.993$

$V_n ((10.3), ASCE 41-17) = knl * V_{Col0} = 468849.466$

$V_{Col} = 468849.466$

$knl = 1.00$

$displacement\_ductility\_demand = 0.26406097$

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

$= 1$  (normal-weight concrete)

$f_c' = 16.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 0.1333213$   
 $V_u = 4519.381$   
 $d = 0.8 \cdot h = 320.00$   
 $N_u = 5925.123$   
 $A_g = 160000.00$   
 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  $V_f(\theta, a)$ , 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:  $\theta = 45^\circ$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 357.00  
 $f_{fe}$  ((11-5), ACI 440) = 259.312  
 $E_f = 64828.00$   
 $f_{fe} = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 340123.561$   
 $b_w = 400.00$

displacement\_ductility\_demand is calculated as  $\delta_u / y$

- Calculation of  $\delta_u / y$  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))  
 $M_y = 7.7038 \times 10^7$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 300.00  
 From table 10.5, ASCE 41-17:  $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 1.3452 \times 10^{13}$   
 $\text{factor} = 0.30$   
 $A_g = 160000.00$   
 $f_c' = 20.00$   
 $N = 5925.123$   
 $E_c \cdot I_g = 4.4841 \times 10^{13}$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta_u$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$   
 $y_{\text{ten}} = 4.8497530 \times 10^{-6}$   
 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  $p_t = 0.00580799$   
 $p_c = 0.00580799$   
 $p_v = 0.00281599$   
 $N = 5925.123$   
 $b = 400.00$

$\lambda = 0.12044818$   
 $y_{comp} = 1.8620192E-005$   
 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,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 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  $I_b/I_d$

Inadequate Lap Length with  $I_b/I_d = 0.30$

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

At local axis: 2

Integration Section: (b)

## Calculation No. 6

column C1, Floor 1

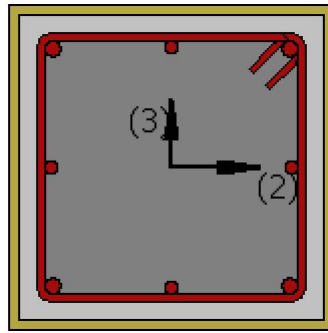
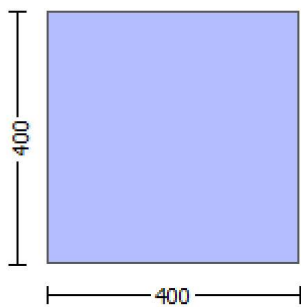
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\theta_u$  )

Edge: End

Local Axis: (2)



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

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcrs

Constant Properties

Knowledge Factor,  $\gamma = 0.95$

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  $135^\circ$ )

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,  $\epsilon_{fu} = 0.01$

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:  $As_{t,ten} = 829.3805$

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

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

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

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  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.7976030E-005$

$M_u = 1.1045E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00207526$

$N = 5926.932$

$f_c = 20.00$

$\phi_c$  (5A.5, TBDY) = 0.002

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)

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

$\phi_{we}$  ((5.4c), TBDY) =  $a_s e * \phi_{s,min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.14357935$

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

$\phi_x = 0.11712639$

$a_f = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A4.4.3(6),  $\phi_f = 2t_f/bw = 0.00508$

$bw = 400.00$

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

$\phi_y = 0.11712639$

$a_f = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A4.4.3(6),  $\phi_f = 2t_f/bw = 0.00508$

$bw = 400.00$

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

$R = 40.00$

Effective FRP thickness,  $t_f = NL * t * \cos(\theta_1) = 1.016$

$f_u, f = 1055.00$   
 $E_f = 64828.00$   
 $u, f = 0.015$   
 $ase((5.4d), TBDY) = 0.24250288$   
 $bo = 340.00$   
 $ho = 340.00$   
 $bi2 = 462400.00$   
 $psh, min = \text{Min}(psh, x, psh, y) = 0.00392699$

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

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

$s = 100.00$   
 $fywe = 555.5556$   
 $fce = 20.00$   
 $\text{From } ((5.A5), TBDY), TBDY: cc = 0.00411734$   
 $c = \text{confinement factor} = 1.21173$   
 $y1 = 0.0012967$   
 $sh1 = 0.0044814$   
 $ft1 = 373.4504$   
 $fy1 = 311.2087$   
 $su1 = 0.00512$   
 $\text{using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor}$   
 $\text{and also multiplied by the shear\_factor according to 15.7.1.4, with}$   
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, min = lb/ld = 0.30$   
 $su1 = 0.4 * esu1\_nominal((5.5), TBDY) = 0.032$   
 $\text{From table 5A.1, TBDY: } esu1\_nominal = 0.08,$   
 $\text{For calculation of } esu1\_nominal \text{ and } y1, sh1, ft1, fy1, \text{ it is considered}$   
 $\text{characteristic value } fsy1 = fs1/1.2, \text{ from table 5.1, TBDY.}$   
 $y1, sh1, ft1, fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE41-17.}$   
 $\text{with } fs1 = fs = 311.2087$   
 $\text{with } Es1 = Es = 200000.00$   
 $y2 = 0.0012967$   
 $sh2 = 0.0044814$   
 $ft2 = 373.4504$   
 $fy2 = 311.2087$   
 $su2 = 0.00512$   
 $\text{using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor}$   
 $\text{and also multiplied by the shear\_factor according to 15.7.1.4, with}$   
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, min = lb/lb, min = 0.30$   
 $su2 = 0.4 * esu2\_nominal((5.5), TBDY) = 0.032$   
 $\text{From table 5A.1, TBDY: } esu2\_nominal = 0.08,$   
 $\text{For calculation of } esu2\_nominal \text{ and } y2, sh2, ft2, fy2, \text{ it is considered}$   
 $\text{characteristic value } fsy2 = fs2/1.2, \text{ from table 5.1, TBDY.}$   
 $y1, sh1, ft1, fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE41-17.}$   
 $\text{with } fs2 = fs = 311.2087$   
 $\text{with } Es2 = Es = 200000.00$   
 $yv = 0.0012967$   
 $shv = 0.0044814$   
 $ftv = 373.4504$   
 $fyv = 311.2087$   
 $suv = 0.00512$   
 $\text{using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor}$   
 $\text{and also multiplied by the shear\_factor according to 15.7.1.4, with}$   
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, min = lb/ld = 0.30$   
 $suv = 0.4 * esuv\_nominal((5.5), TBDY) = 0.032$   
 $\text{From table 5A.1, TBDY: } esuv\_nominal = 0.08,$

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

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

$Mu = MR_c$  (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),  $pf = 2tf/bw = 0.00508$

$bw = 400.00$

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

$fy = 0.11712639$

$af = 0.57333333$



$b = 400.00$   
 $h = 400.00$   
 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:  $cc = 0.00411734$   
 $c = \text{confinement factor} = 1.21173$   
 $y1 = 0.0012967$   
 $sh1 = 0.0044814$   
 $ft1 = 373.4504$   
 $fy1 = 311.2087$   
 $su1 = 0.00512$   
 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  $\min(1, 1.25*(lb/ld)^{2/3})$ , 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/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

```

$b = 400.00$   
 $h = 400.00$   
 From EC8 A4.4.3(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 A4.4.3(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:  $cc = 0.00411734$   
 $c = \text{confinement factor} = 1.21173$   
 $y1 = 0.0012967$   
 $sh1 = 0.0044814$   
 $ft1 = 373.4504$   
 $fy1 = 311.2087$   
 $su1 = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou,min = lb/l_d = 0.30$   
 $su1 = 0.4*esu1\_nominal((5.5), TBDY) = 0.032$   
 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  $es_{u2\_nominal}$  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  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , 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  
 $lo/lo_{u,min} = lb/ld = 0.30$   
 $suv = 0.4 \cdot es_{u\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $es_{u\_nominal} = 0.08$ ,  
 considering characteristic value  $fs_{yv} = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $es_{u\_nominal}$  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  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs_v = fs = 311.2087$   
 with  $Es_v = Es = 200000.00$   
 $1 = Asl_{ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.09037478$   
 $2 = Asl_{com}/(b \cdot d) \cdot (fs_2/f_c) = 0.09037478$   
 $v = Asl_{mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.04381808$   
 and confined core properties:  
 $b = 340.00$   
 $d = 327.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 24.23468$   
 $cc (5A.5, TBDY) = 0.00411734$   
 $c = \text{confinement factor} = 1.21173$   
 $1 = Asl_{ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.1160777$   
 $2 = Asl_{com}/(b \cdot d) \cdot (fs_2/f_c) = 0.1160777$   
 $v = Asl_{mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.0562801$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.2021744$   
 $Mu = MR_c (4.14) = 1.1045E+008$   
 $u = su (4.1) = 1.7976030E-005$

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:

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

Final value of  $\alpha$ :  $\alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.018$

The Shear\_factor is considered equal to 1 (pure moment strength)

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

we ((5.4c), TBDY) =  $\alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\alpha_x, \alpha_y) = 0.14357935$

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

-----  
 $\alpha_x = 0.11712639$

$\alpha_f = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A4.4.3(6),  $\rho_f = 2t_f/bw = 0.00508$

$bw = 400.00$

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

-----  
 $\alpha_y = 0.11712639$

$\alpha_f = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A4.4.3(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,  $t_f = N L^* t \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f1} = 0.015$

$\alpha_{se}$  ((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

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

No stirrups,  $n_s = 2.00$

$b_k = 400.00$

-----  
 $\rho_{sh,y}$  (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:  $\alpha_c = 0.00411734$

$\alpha_c$  = 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

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

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

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

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

characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

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

with  $fs_1 = fs = 311.2087$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.0012967$

$sh_2 = 0.0044814$

$ft_2 = 373.4504$

```

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 = 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

```

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Calculation of ratio lb/ld

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Inadequate Lap Length with lb/ld = 0.30

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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\* $V_{ColO}$

$V_{ColO} = 524051.339$

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).

$\lambda = 1$  (normal-weight concrete)  
 $f'_c = 20.00$ , but  $f'_c \cdot 0.5 \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu = 1.8671199 \times 10^{-11}$   
 $V_u = 6.9434686 \times 10^{-31}$   
 $d = 0.8 \cdot h = 320.00$   
 $N_u = 5926.932$   
 $A_g = 160000.00$   
 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  $\text{Col} = 1.00$   
 $s/d = 0.3125$   
 $V_f ((11-3)-(11.4), \text{ACI 440}) = 188111.148$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$   
 $d_{fv} = d$  (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,  $V_{r2} = 524051.339$   
 $V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE 41-17}) = k_{nl} \cdot V_{\text{Col}0}$   
 $V_{\text{Col}0} = 524051.339$   
 $k_{nl} = 1$  (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  $f'_c \cdot 0.5 \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu = 1.8671199 \times 10^{-11}$   
 $V_u = 6.9434686 \times 10^{-31}$   
 $d = 0.8 \cdot h = 320.00$   
 $N_u = 5926.932$   
 $A_g = 160000.00$   
 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  $\text{Col} = 1.00$   
 $s/d = 0.3125$   
 $V_f ((11-3)-(11.4), \text{ACI 440}) = 188111.148$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:

total thickness per orientation,  $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (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,  $\phi = 0.95$   
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  $135^\circ$ )  
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,  $\epsilon_{fu} = 0.01$   
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,  $V_a = 4.2515079\text{E-}047$   
EDGE -B-  
Shear Force,  $V_b = -4.2515079\text{E-}047$   
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  
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 1.1045E+008$   
 $\mu_{u1+} = 1.1045E+008$ , 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  
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 1.1045E+008$   
 $\mu_{u2+} = 1.1045E+008$ , 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  $\mu_{u1+}$

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\mu_u = 1.7976030E-005$   
 $\mu_u = 1.1045E+008$

with full section properties:

$b = 400.00$   
 $d = 357.00$   
 $d' = 43.00$   
 $v = 0.00207526$   
 $N = 5926.932$   
 $f_c = 20.00$   
 $\alpha = (5A_s, TBDY) = 0.002$

Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} * \max(\mu_u, \alpha) = 0.018$

The Shear\_factor is considered equal to 1 (pure moment strength)

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

we ((5.4c), TBDY)  $= \alpha s_e * \min(f_{ywe}/f_{ce} + \min(f_x, f_y)) = 0.14357935$

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

$f_x = 0.11712639$   
 $\alpha f = 0.57333333$   
 $b = 400.00$   
 $h = 400.00$   
 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,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_u, f = 1055.00$

$E_f = 64828.00$

$u, f = 0.015$

$a_s((5.4d), TBDY) = 0.24250288$

$b_o = 340.00$

$h_o = 340.00$

$b_{i2} = 462400.00$

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

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

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

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  $((5.4s), TBDY)$ , 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

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

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

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

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

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , 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

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

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

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

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

$y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , 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

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

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

From table 5A.1, TBDY:  $\varepsilon_{suv\_nominal} = 0.08$ ,  
 considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $\varepsilon_{suv\_nominal}$  and  $\gamma_v$ ,  $\gamma_{shv}$ ,  $\gamma_{ftv}$ ,  $\gamma_{fyv}$ , it is considered  
 characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $\gamma_1$ ,  $\gamma_{sh1}$ ,  $\gamma_{ft1}$ ,  $\gamma_{fy1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $f_{sv} = f_s = 311.2087$   
 with  $\varepsilon_{sv} = \varepsilon_s = 200000.00$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.09037478$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09037478$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.04381808$

and confined core properties:

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

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

---->

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

---->

$\mu_u \text{ (4.9)} = 0.2021744$   
 $\mu_u = M_{Rc} \text{ (4.14)} = 1.1045E+008$   
 $u = \mu_u \text{ (4.1)} = 1.7976030E-005$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{u1}$ -

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.7976030E-005$   
 $\mu_u = 1.1045E+008$

with full section properties:

$b = 400.00$   
 $d = 357.00$   
 $d' = 43.00$   
 $v = 0.00207526$   
 $N = 5926.932$   
 $f_c = 20.00$   
 $cc \text{ (5A.5, TBDY)} = 0.002$   
 Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} \cdot \text{Max}(\mu_u, cc) = 0.018$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\mu_u = 0.018$   
 $\mu_{ue} \text{ ((5.4c), TBDY)} = a_{se} \cdot \gamma_{sh,min} \cdot f_{ywe}/f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.14357935$   
 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)

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

$\mu_{fy} = 0.11712639$

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/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  $\text{Min}(1, 1.25*(lb/lb)^{2/3})$ , 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  $\text{Min}(1, 1.25*(lb/lb)^{2/3})$ , 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/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  
From EC8 A4.4.3(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 A4.4.3(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,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 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  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , 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  
 $lo/lo_{u,min} = lb/ld = 0.30$   
 $suv = 0.4 \cdot es_{u2\_nominal} \cdot ((5.5), TBDY) = 0.032$   
 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  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs_v = fs = 311.2087$   
 with  $Es_v = Es = 200000.00$   
 $1 = Asl_{ten}/(b \cdot d) \cdot (fs_1/fc) = 0.09037478$   
 $2 = Asl_{com}/(b \cdot d) \cdot (fs_2/fc) = 0.09037478$   
 $v = Asl_{mid}/(b \cdot d) \cdot (fs_v/fc) = 0.04381808$   
 and confined core properties:  
 $b = 340.00$   
 $d = 327.00$   
 $d' = 13.00$   
 $f_{cc} \text{ (5A.2, TBDY)} = 24.23468$   
 $cc \text{ (5A.5, TBDY)} = 0.00411734$   
 $c = \text{confinement factor} = 1.21173$   
 $1 = Asl_{ten}/(b \cdot d) \cdot (fs_1/fc) = 0.1160777$   
 $2 = Asl_{com}/(b \cdot d) \cdot (fs_2/fc) = 0.1160777$   
 $v = Asl_{mid}/(b \cdot d) \cdot (fs_v/fc) = 0.0562801$   
 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  $lb/ld$   
 -----

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:

$b = 400.00$   
 $d = 357.00$   
 $d' = 43.00$   
 $v = 0.00207526$   
 $N = 5926.932$   
 $fc = 20.00$

$c_o$  (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) =  $a_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$   
 where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

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

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

$R = 40.00$   
 Effective FRP thickness,  $t_f = N_L * t * \text{Cos}(\theta_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{f,f} = 0.015$   
 $a_{se}$  ((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 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,  $n_s = 2.00$   
 $b_k = 400.00$

$s = 100.00$   
 $f_{ywe} = 555.5556$   
 $f_{ce} = 20.00$   
 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  
 $l_o/l_{ou,\min} = l_b/l_d = 0.30$   
 $su_1 = 0.4 * esu_{1\_nominal}$  ((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  $Es_1 = Es = 200000.00$   
 $y_2 = 0.0012967$   
 $sh_2 = 0.0044814$



```

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/lo,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/lo,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 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/lb

Inadequate Lap Length with lb/lb = 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) ' $V_s = A_v \cdot f_y \cdot d / s$ ' 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)  
 $M/Vd = 2.00$   
 $\mu_u = 4.6307395E-012$   
 $\nu_u = 4.2515079E-047$   
 $d = 0.8 \cdot h = 320.00$   
 $N_u = 5926.932$   
 $A_g = 160000.00$   
 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  $\text{Col} = 1.00$   
 $s/d = 0.3125$   
 $V_f ((11-3)-(11.4), \text{ACI 440}) = 188111.148$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 357.00  
 $f_{fe} ((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , 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,  $V_{r2} = 524051.339$   
 $V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE 41-17}) = k_n l \cdot V_{\text{Col}0}$   
 $V_{\text{Col}0} = 524051.339$   
 $k_n l = 1$  (zero step-static loading)

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

$\lambda = 1$  (normal-weight concrete)  
 $f'_c = 20.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 4.6307395E-012$   
 $\nu_u = 4.2515079E-047$   
 $d = 0.8 \cdot h = 320.00$   
 $N_u = 5926.932$   
 $A_g = 160000.00$   
 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  $\text{Col} = 1.00$   
 $s/d = 0.3125$   
 $V_f ((11-3)-(11.4), \text{ACI 440}) = 188111.148$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$   
 $df_v = d$  (figure 11.2, ACI 440) = 357.00  
 $ffe$  ((11-5), ACI 440) = 259.312  
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 380269.701$   
 $bw = 400.00$

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,  $\gamma = 0.95$   
 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,  $ff_u = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $ef_u = 0.01$   
 Number of directions,  $\text{NoDir} = 1$   
 Fiber orientations,  $bi: 0.00^\circ$   
 Number of layers,  $NL = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -1.2603819\text{E-}010$   
 Shear Force,  $V2 = 4519.381$   
 Shear Force,  $V3 = 1.5368441\text{E-}013$   
 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:  $As_{l,com} = 829.3805$

-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  $y$  -

$y = (My * Ls / 3) / Eleff = 0.0028634$  ((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:  $Eleff = factor * Ec * Ig = 1.3452E+013$

$factor = 0.30$

$Ag = 160000.00$

$fc' = 20.00$

$N = 5925.123$

$Ec * Ig = 4.4841E+013$

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)  $f_y = \text{Min}(f_y, 1.25 * f_y * (lb/d)^{2/3}) = 248.9669$

$d = 357.00$

$y = 0.28100837$

$A = 0.01459862$

$B = 0.00825179$

with  $pt = 0.00580799$

$pc = 0.00580799$

$pv = 0.00281599$

$N = 5925.123$

$b = 400.00$

$" = 0.12044818$

$y_{comp} = 1.8620192E-005$

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

effective strain from (12.5) and (12.12),  $efe = 0.004$

$fu = 0.01$

$Ef = 64828.00$

$Ec = 21019.039$

$y = 0.27898785$

$A = 0.0143201$

$B = 0.00808514$

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  $l_b/l_d \geq 1$

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.

$N_{UD} = 5925.123$

$A_g = 160000.00$

$f_{cE} = 20.00$

$f_{yE} = f_{yIE} = 0.00$

$p_l = \text{Area\_Tot\_Long\_Rein}/(b*d) = 0.01443197$

$b = 400.00$

$d = 357.00$

$f_{cE} = 20.00$

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

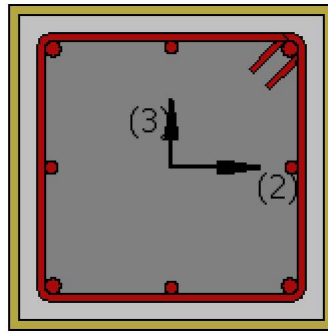
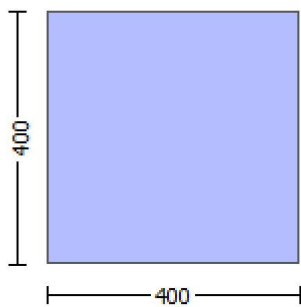
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

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  $\gamma$  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,  $NoDir = 1$

Fiber orientations,  $bi: 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment,  $M_a = 5.8739332E-010$

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

EDGE -B-

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

Shear Force,  $V_b = 1.5368441\text{E-}013$   
 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:  $As_{ten} = 829.3805$   
     -Compression:  $As_{com} = 829.3805$   
     -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  $V_R = V_n = 445406.993$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{Col0} = 468849.466$   
 $V_{Col} = 468849.466$   
 $k_n = 1.00$   
 $displacement\_ductility\_demand = 0.00$

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

$= 1$  (normal-weight concrete)  
 $f'_c = 16.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.2603819\text{E-}010$   
 $V_u = 1.5368441\text{E-}013$   
 $d = 0.8 \cdot h = 320.00$   
 $N_u = 5925.123$   
 $A_g = 160000.00$   
 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  $Col = 1.00$   
 $s/d = 0.3125$   
 $V_f$  ((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:  $\theta_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) =  $357.00$   
 $f_{fe}$  ((11-5), ACI 440) =  $259.312$   
 $E_f = 64828.00$   
 $f_{fe} = 0.004$ , 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  $\Delta / y$

- Calculation of  $\Delta / y$  for END B -  
 for rotation axis 2 and integ. section (b)

From analysis, chord rotation  $\theta = 9.0140030\text{E-}021$   
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.0028634$  ((4.29), Biskinis Phd))  
 $M_y = 7.7038\text{E+}007$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) =  $1500.00$

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

factor = 0.30

$A_g = 160000.00$

$f_c' = 20.00$

$N = 5925.123$

$E_c * I_g = 4.4841E+013$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 21019.039$

$y = 0.27898785$

$A = 0.0143201$

$B = 0.00808514$

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

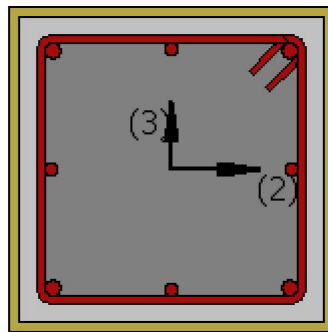
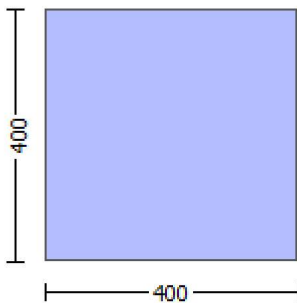
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\phi$ )

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,  $\phi = 0.95$

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,  $\epsilon_{fu} = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = -6.9434686E-031$

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:  $As_{c,com} = 829.3805$

-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

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

$\mu_{1+} = 1.1045E+008$ , 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  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 1.7976030E-005$

$\mu_u = 1.1045E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00207526$

$N = 5926.932$

$f_c = 20.00$

$\phi_o$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_o) = 0.018$

The Shear\_factor is considered equal to 1 (pure moment strength)

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

we ((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)

$$f_x = 0.11712639$$

$$af = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$f_y = 0.11712639$$

$$af = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$R = 40.00$$

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

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

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

$$bo = 340.00$$

$$ho = 340.00$$

$$bi2 = 462400.00$$

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

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

$$Ash = Astir \cdot ns = 78.53982$$

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

$$bk = 400.00$$

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

$$Ash = Astir \cdot ns = 78.53982$$

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

$$bk = 400.00$$

$$s = 100.00$$

$$fywe = 555.5556$$

$$fce = 20.00$$

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

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

$$y1 = 0.0012967$$

$$sh1 = 0.0044814$$

$$ft1 = 373.4504$$

$$fy1 = 311.2087$$

$$su1 = 0.00512$$

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

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

$$su1 = 0.4 \cdot esu1\_nominal \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1\_nominal = 0.08,$$

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  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , 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 Min(1,1.25*(lb/lb,min)^ 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 Min(1,1.25*(lb/lb,min)^ 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/lb,min

Inadequate Lap Length with lb/lb,min = 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

$v = 0.00207526$   
 $N = 5926.932$   
 $f_c = 20.00$   
 $\alpha (5A.5, TBDY) = 0.002$   
 Final value of  $\alpha$ :  $\alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.018$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\alpha = 0.018$   
 $\omega (5.4c, TBDY) = \alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$   
 where  $f = \alpha * \rho_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

---

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

---

$f_y = 0.11712639$   
 $\alpha_f = 0.57333333$   
 $b = 400.00$   
 $h = 400.00$   
 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,  $t_f = N L^* t \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{f,f} = 0.015$   
 $\alpha_{se} ((5.4d), TBDY) = 0.24250288$   
 $b_o = 340.00$   
 $h_o = 340.00$   
 $b_{i2} = 462400.00$   
 $\rho_{sh,\min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.00392699$

---

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

---

$\rho_{sh,y} (5.4d) = 0.00392699$   
 $A_{sh} = A_{stir} * n_s = 78.53982$   
 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:  $\alpha_c = 0.00411734$   
 $\alpha_c = \text{confinement factor} = 1.21173$   
 $y_1 = 0.0012967$   
 $sh_1 = 0.0044814$   
 $ft_1 = 373.4504$   
 $fy_1 = 311.2087$   
 $su_1 = 0.00512$   
 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  
 $l_o/l_{ou,\min} = l_b/l_d = 0.30$   
 $su_1 = 0.4 * esu_{1\_nominal} ((5.5), TBDY) = 0.032$   
 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 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 lb/d = 0.30

Calculation of Mu2+

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 1.7976030E-005$$

$$\mu_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

The Shear\_factor is considered equal to 1 (pure moment strength)

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

$$\omega_e \text{ ((5.4c), TBDY)} = a_{se} * \frac{f_{ywe}}{f_{ce}} + \text{Min}(\phi_x, \phi_y) = 0.14357935$$

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

$$\phi_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$\phi_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \cos(\beta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

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

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

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

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

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

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

$$b_k = 400.00$$

$$\phi_{sh,y} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$f_{t1} = 373.4504$$

$$f_{y1} = 311.2087$$

$$su_1 = 0.00512$$

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
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 = 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  $l_b/l_d = 0.30$

Calculation of  $\mu_2$ -

Calculation of ultimate curvature  $\mu$  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)

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

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

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

$$\mu_{fx} = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A4.4.3(6), } \mu_{pf} = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

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

$$\mu_{fy} = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A4.4.3(6), } \mu_{pf} = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$\mu_{u,f} = 0.015$$

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

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

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

$$\mu_{psh,x} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$\mu_{psh,y} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

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

```

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 = 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

```

--->

$$\mu (4.9) = 0.2021744$$

$$\mu = MRC (4.14) = 1.1045E+008$$

$$u = \mu (4.1) = 1.7976030E-005$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

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

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

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

$$V_{Col0} = 524051.339$$

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

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).

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

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

$$M/Vd = 2.00$$

$$\mu_u = 1.8671199E-011$$

$$V_u = 6.9434686E-031$$

$$d = 0.8 * h = 320.00$$

$$N_u = 5926.932$$

$$A_g = 160000.00$$

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

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

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

$$s/d = 0.3125$$

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

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

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

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

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

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

$$V_f = \min(|V_f(45, 1)|, |V_f(-45, a_1)|), \text{ with:}$$

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

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

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

$$E_f = 64828.00$$

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

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

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

$$b_w = 400.00$$

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

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

$$V_{Col0} = 524051.339$$

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

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).

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

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

$$M/Vd = 2.00$$

$\mu_u = 1.8671199E-011$   
 $\mu_v = 6.9434686E-031$   
 $d = 0.8 \cdot h = 320.00$   
 $Nu = 5926.932$   
 $Ag = 160000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = 223402.144$   
 $Av = 157079.633$   
 $f_y = 444.4444$   
 $s = 100.00$   
 $V_s$  is multiplied by  $\text{Col} = 1.00$   
 $s/d = 0.3125$   
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 188111.148$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  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,  $tf1 = NL \cdot t / \text{NoDir} = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 357.00  
 $ffe ((11-5), \text{ACI } 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 380269.701$   
 $bw = 400.00$

-----  
 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  $135^\circ$ )  
 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,  $\epsilon_{fu} = 0.01$   
Number of directions,  $NoDir = 1$   
Fiber orientations,  $b_i = 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 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:  $As_{c,mid} = 402.1239$

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  
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 1.1045E+008$   
 $\mu_{u1+} = 1.1045E+008$ , 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  
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 1.1045E+008$   
 $\mu_{u2+} = 1.1045E+008$ , 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 $\mu_{u1+}$

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\mu_u = 1.7976030E-005$   
 $\mu_u = 1.1045E+008$

with full section properties:

$b = 400.00$   
 $d = 357.00$   
 $d' = 43.00$   
 $v = 0.00207526$   
 $N = 5926.932$   
 $f_c = 20.00$   
 $\alpha = 0.002$   
Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} * \max(\mu_u, \alpha) = 0.018$   
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY:  $\mu_u = 0.018$

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  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , 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  
 $l_o/l_{ou,min} = l_b/l_d = 0.30$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsy_v = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsy_v = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs_v = fs = 311.2087$   
 with  $Es_v = Es = 200000.00$   
 $1 = Asl_{ten}/(b * d) * (fs_1/f_c) = 0.09037478$   
 $2 = Asl_{com}/(b * d) * (fs_2/f_c) = 0.09037478$   
 $v = Asl_{mid}/(b * d) * (fs_v/f_c) = 0.04381808$   
 and confined core properties:  
 $b = 340.00$   
 $d = 327.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 24.23468$   
 $cc (5A.5, TBDY) = 0.00411734$   
 $c = \text{confinement factor} = 1.21173$   
 $1 = Asl_{ten}/(b * d) * (fs_1/f_c) = 0.1160777$   
 $2 = Asl_{com}/(b * d) * (fs_2/f_c) = 0.1160777$   
 $v = Asl_{mid}/(b * d) * (fs_v/f_c) = 0.0562801$   
 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  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.7976030E-005$$

$$Mu = 1.1045E+008$$

-----  
 with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$d' = 43.00$   
 $v = 0.00207526$   
 $N = 5926.932$   
 $f_c = 20.00$   
 $\alpha (5A.5, TBDY) = 0.002$   
 Final value of  $\alpha$ :  $\alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.018$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\alpha = 0.018$   
 $\alpha_e ((5.4c), TBDY) = \alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$   
 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,  $t_f = N L * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $\alpha_e ((5.4d), TBDY) = 0.24250288$   
 $b_o = 340.00$   
 $h_o = 340.00$   
 $b_{i2} = 462400.00$   
 $p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$

$p_{sh,x} (5.4d) = 0.00392699$   
 $A_{sh} = A_{stir} * n_s = 78.53982$   
 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:  $\alpha_c = 0.00411734$   
 $\alpha = \text{confinement factor} = 1.21173$   
 $y_1 = 0.0012967$   
 $sh_1 = 0.0044814$   
 $ft_1 = 373.4504$   
 $fy_1 = 311.2087$   
 $su_1 = 0.00512$   
 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  
 $l_o / l_{ou,\min} = l_b / l_d = 0.30$   
 $su_1 = 0.4 * esu_{1\_nominal} ((5.5), TBDY) = 0.032$   
 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 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 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/lb

Inadequate Lap Length with lb/lb = 0.30

Calculation of Mu2+

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 1.7976030E-005$$

$$M_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

The Shear\_factor is considered equal to 1 (pure moment strength)

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

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

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

$$\phi_{fx} = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$\phi_{fy} = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

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

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

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

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

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

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

$$b_k = 400.00$$

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

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$f_{t1} = 373.4504$$

$$f_{y1} = 311.2087$$

$$su_1 = 0.00512$$

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  
 $l_o/l_{ou,min} = l_b/l_d = 0.30$   
 $su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,  
For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
with  $fs_1 = fs = 311.2087$   
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  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
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  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , 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  
 $l_o/l_{ou,min} = l_b/l_d = 0.30$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
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  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
with  $fsv = fs = 311.2087$   
with  $Esv = Es = 200000.00$   
 $1 = Asl_{ten}/(b * d) * (fs_1/f_c) = 0.09037478$   
 $2 = Asl_{com}/(b * d) * (fs_2/f_c) = 0.09037478$   
 $v = Asl_{mid}/(b * d) * (fsv/f_c) = 0.04381808$   
and confined core properties:  
 $b = 340.00$   
 $d = 327.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 24.23468$   
 $cc (5A.5, TBDY) = 0.00411734$   
 $c = \text{confinement factor} = 1.21173$   
 $1 = Asl_{ten}/(b * d) * (fs_1/f_c) = 0.1160777$   
 $2 = Asl_{com}/(b * d) * (fs_2/f_c) = 0.1160777$   
 $v = Asl_{mid}/(b * d) * (fsv/f_c) = 0.0562801$   
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  $\mu_2$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.7976030E-005$$

$$\mu_2 = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u = \text{shear\_factor} * \text{Max}(c_u, c_o) = 0.018$$

The Shear\_factor is considered equal to 1 (pure moment strength)

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

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

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

$$f_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$f_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

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

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

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

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

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

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

$$b_k = 400.00$$

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

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

From ((5A.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  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/ld = 0.30$   
 $su1 = 0.4 * esu1\_nominal ((5.5), TBDY) = 0.032$   
 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  $fs1 = fs = 311.2087$   
 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  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/lb, \min = 0.30$   
 $su2 = 0.4 * esu2\_nominal ((5.5), TBDY) = 0.032$   
 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  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/ld = 0.30$   
 $suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$   
 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:  
 $b = 340.00$   
 $d = 327.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 24.23468$   
 $cc (5A.5, TBDY) = 0.00411734$   
 $c = \text{confinement factor} = 1.21173$   
 $1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.1160777$   
 $2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.1160777$   
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.0562801$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->

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

---->

$$\mu_u(4.9) = 0.2021744$$

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

$$u = \mu_u(4.1) = 1.7976030E-005$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

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

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).

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

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

$$M/Vd = 2.00$$

$$\mu_u = 4.6307395E-012$$

$$V_u = 4.2515079E-047$$

$$d = 0.8 * h = 320.00$$

$$N_u = 5926.932$$

$$A_g = 160000.00$$

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

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

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

$$s/d = 0.3125$$

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

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

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

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

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

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

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

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

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

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

$$E_f = 64828.00$$

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

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

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

$$b_w = 400.00$$

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).

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

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

$M/Vd = 2.00$   
 $\mu_u = 4.6307395E-012$   
 $\mu_v = 4.2515079E-047$   
 $d = 0.8 \cdot h = 320.00$   
 $N_u = 5926.932$   
 $A_g = 160000.00$   
 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  $\text{Col} = 1.00$   
 $s/d = 0.3125$   
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 188111.148$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = \theta_1 = 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$   
 $d_{fv} = d$  (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:  $V_s + V_f \leq 380269.701$   
 $b_w = 400.00$

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

-----  
 Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1  
 At local axis: 3  
 Integration Section: (b)  
 Section Type: rcrs

Constant Properties

-----  
 Knowledge Factor,  $\phi = 0.95$   
 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  $135^\circ$ )  
 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,  $\epsilon_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i = 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = 0.1333213$   
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:  $A_{st} = 0.00$   
-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  $\phi_{u,R} = \phi_u = 0.00054405$   
 $\phi_u = \phi_y + \phi_p = 0.00057268$

- Calculation of  $\phi_y$  -

$\phi_y = (M_y * L_s / 3) / E_{eff} = 0.00057268$  ((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:  $E_{eff} = factor * E_c * I_g = 1.3452E+013$   
 $factor = 0.30$   
 $A_g = 160000.00$   
 $f_c' = 20.00$   
 $N = 5925.123$   
 $E_c * I_g = 4.4841E+013$

#### Calculation of Yielding Moment $M_y$

Calculation of  $\phi_y$  and  $M_y$  according to Annex 7 -

$\phi_y = \min(\phi_{y,ten}, \phi_{y,com})$   
 $\phi_{y,ten} = 4.8497530E-006$   
with ((10.1), ASCE 41-17)  $\phi_y = \min(\phi_y, 1.25 * \phi_y * (I_b / I_d)^{2/3}) = 248.9669$   
 $d = 357.00$   
 $\phi_y = 0.28100837$   
 $A = 0.01459862$   
 $B = 0.00825179$   
with  $p_t = 0.00580799$   
 $p_c = 0.00580799$   
 $p_v = 0.00281599$   
 $N = 5925.123$   
 $b = 400.00$   
 $\phi_y = 0.12044818$   
 $\phi_{y,comp} = 1.8620192E-005$   
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,  $t_f = N_L * t * \cos(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 21019.039$   
 $\gamma = 0.27898785$   
 $A = 0.0143201$   
 $B = 0.00808514$   
 with  $E_s = 200000.00$

Calculation of ratio  $I_b/I_d$

Inadequate Lap Length with  $I_b/I_d = 0.30$

- Calculation of  $p$  -

From table 10-8:  $p = 0.00$

with:

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

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.

$N_{UD} = 5925.123$

$A_g = 160000.00$

$f'_{cE} = 20.00$

$f_{ytE} = f_{yIE} = 0.00$

$p_l = \text{Area\_Tot\_Long\_Rein} / (b * d) = 0.01443197$

$b = 400.00$

$d = 357.00$

$f'_{cE} = 20.00$

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

At local axis: 3

Integration Section: (b)

**Calculation No. 9**

column C1, Floor 1

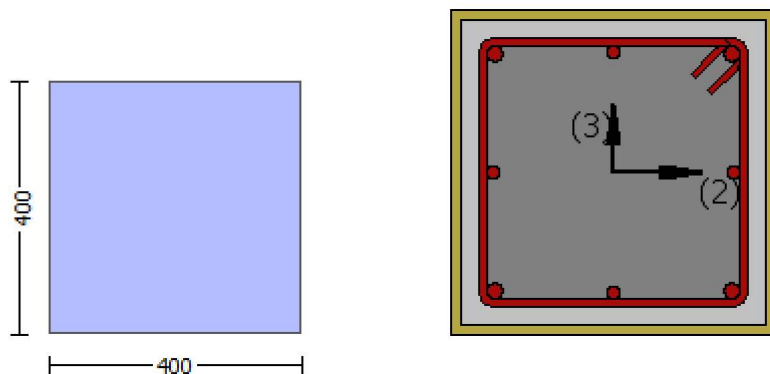
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

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  $\gamma$  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: Aslc = 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 VR = \*Vn = 384262.145  
Vn ((10.3), ASCE 41-17) = knl\*VCol0 = 404486.468  
VCol = 404486.468  
knl = 1.00  
displacement\_ductility\_demand = 0.06202861

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

= 1 (normal-weight concrete)  
fc' = 16.00, but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
M/Vd = 4.00  
Mu = 1.6965E+007  
Vu = 5652.966  
d = 0.8\*h = 320.00  
Nu = 5924.669  
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  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
where  $\alpha$  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 ai,  
as well as for 2 crack directions,  $\alpha = 45^\circ$  and  $\alpha = -45^\circ$  to take into consideration the cyclic seismic loading.  
orientation 1:  $\alpha_1 = b_1 + 90^\circ = 90.00$   
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 <= 340123.561

bw = 400.00

displacement\_ductility\_demand is calculated as  $\phi_y$

- Calculation of  $\phi_y$  for END A -  
for rotation axis 3 and integ. section (a)

From analysis, chord rotation  $\theta = 0.00035536$   
 $\phi_y = (M_y * L_s / 3) / E_{eff} = 0.00572891$  ((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  $\phi_y$  and  $M_y$  according to Annex 7 -

$\phi_y = \min(\phi_{y\_ten}, \phi_{y\_com})$   
 $\phi_{y\_ten} = 4.8497516E-006$   
with ((10.1), ASCE 41-17)  $f_y = \min(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 248.9669$   
 $d = 357.00$   
 $\phi_y = 0.28100816$   
 $A = 0.01459861$   
 $B = 0.00825178$   
with  $p_t = 0.00580799$   
 $p_c = 0.00580799$   
 $p_v = 0.00281599$   
 $N = 5924.669$   
 $b = 400.00$   
 $\phi_y = 0.12044818$   
 $\phi_{y\_comp} = 1.8620196E-005$   
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,  $t_f = N L * t * \cos(b_1) = 1.016$   
effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 21019.039$   
 $\phi_y = 0.2789878$   
 $A = 0.01432011$   
 $B = 0.00808514$   
with  $E_s = 200000.00$

Calculation of ratio  $I_b / I_d$

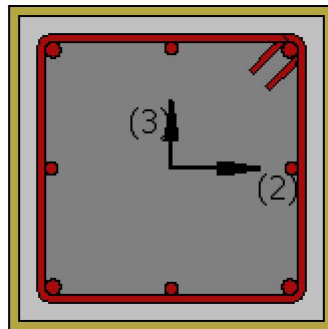
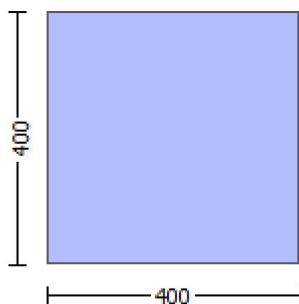
Inadequate Lap Length with  $I_b / I_d = 0.30$

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

At local axis: 2  
Integration Section: (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 (  $\phi$  )  
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,  $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

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,  $ε_{fu} = 0.01$   
 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:  $As_{t,ten} = 829.3805$   
   -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  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\phi_u = 1.7976030E-005$   
 $M_u = 1.1045E+008$

with full section properties:

$b = 400.00$   
 $d = 357.00$   
 $d' = 43.00$   
 $v = 0.00207526$

$N = 5926.932$   
 $f_c = 20.00$   
 $\alpha (5A.5, TBDY) = 0.002$   
 Final value of  $\alpha$ :  $\alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.018$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\alpha = 0.018$   
 $\alpha_e ((5.4c), TBDY) = \alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$   
 where  $f = \alpha * \rho_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

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

$f_y = 0.11712639$   
 $\alpha_f = 0.57333333$   
 $b = 400.00$   
 $h = 400.00$   
 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,  $t_f = N L^* t \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{f,f} = 0.015$   
 $\alpha_e ((5.4d), TBDY) = 0.24250288$   
 $b_o = 340.00$   
 $h_o = 340.00$   
 $b_{i2} = 462400.00$   
 $\rho_{sh,\min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.00392699$

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

$\rho_{sh,y} (5.4d) = 0.00392699$   
 $A_{sh} = A_{stir} * n_s = 78.53982$   
 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:  $\alpha_c = 0.00411734$   
 $\alpha_c = \text{confinement factor} = 1.21173$   
 $y_1 = 0.0012967$   
 $sh_1 = 0.0044814$   
 $ft_1 = 373.4504$   
 $fy_1 = 311.2087$   
 $su_1 = 0.00512$   
 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  
 $l_o/l_{ou,\min} = l_b/l_d = 0.30$   
 $su_1 = 0.4 * esu_{1\_nominal} ((5.5), TBDY) = 0.032$   
 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  $Es_1 = Es = 200000.00$

```

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 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/lb

Inadequate Lap Length with lb/lb = 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 A4.4.3(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 A4.4.3(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

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00392699$

$psh_x (5.4d) = 0.00392699$

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

$fy_{we} = 555.5556$

$f_{ce} = 20.00$

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

$l_o/l_{ou,min} = l_b/l_d = 0.30$   
 $su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$   
 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  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , 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  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , 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  
 $l_o/l_{ou,min} = l_b/l_d = 0.30$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fsv = fs = 311.2087$   
 with  $Esv = Es = 200000.00$   
 $1 = Asl_{ten}/(b * d) * (fs_1/f_c) = 0.09037478$   
 $2 = Asl_{com}/(b * d) * (fs_2/f_c) = 0.09037478$   
 $v = Asl_{mid}/(b * d) * (fsv/f_c) = 0.04381808$

and confined core properties:

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

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 $\mu_{2+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.7976030E-005$$

$$\mu_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$\nu = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \alpha_{co}) = 0.018$$

The Shear\_factor is considered equal to 1 (pure moment strength)

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

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

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

$$\mu_{fx} = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$\mu_{fy} = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(\beta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$\mu_{u,f} = 0.015$$

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

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

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

$$\mu_{psh,x} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$\mu_{psh,y} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

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

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

```

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 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 = 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<sub>d</sub>

Inadequate Lap Length with lb/l<sub>d</sub> = 0.30

Calculation of Mu<sub>2</sub>-

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<sub>c</sub> = 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 stirrups, ns = 2.00  
bk = 400.00

s = 100.00

fywe = 555.5556

fce = 20.00

From ((5A.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 Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 524051.339$

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

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

$V_{Col0} = 524051.339$

$k_{nl} = 1$  (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)  
 $f'_c = 20.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.8671199E-011$   
 $\mu_v = 6.9434686E-031$   
 $d = 0.8 * h = 320.00$   
 $N_u = 5926.932$   
 $A_g = 160000.00$   
 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  $\lambda = 1.00$   
 $s/d = 0.3125$   
 $V_f((11-3)-(11.4), ACI 440) = 188111.148$   
 $\lambda = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = 45^\circ + 90^\circ = 135^\circ$   
 $V_f = \min(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L * t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 357.00  
 $f_{fe}((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_{fe} = 0.004$ , 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,  $V_{r2} = 524051.339$

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

$V_{Col0} = 524051.339$

$k_{nl} = 1$  (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).

= 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)  $\sin + \cos$  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  $\theta_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$ , with:

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

$d_{fv} = d$  (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  $f_u = 0.01$

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  $l_o/l_{o,min} = 0.30$   
 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,  $\epsilon_{fu} = 0.01$   
 Number of directions,  $NoDir = 1$   
 Fiber orientations,  $b_i = 0.00^\circ$   
 Number of layers,  $NL = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 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:  $As_{l,com} = 829.3805$   
   -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  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\phi_u = 1.7976030E-005$   
 $M_u = 1.1045E+008$

with full section properties:

$b = 400.00$   
 $d = 357.00$   
 $d' = 43.00$

$v = 0.00207526$   
 $N = 5926.932$   
 $fc = 20.00$   
 $co (5A.5, TBDY) = 0.002$   
 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,  $tf = NL * t * \cos(b1) = 1.016$   
 $fu_f = 1055.00$   
 $Ef = 64828.00$   
 $u_f = 0.015$   
 $ase ((5.4d), TBDY) = 0.24250288$   
 $bo = 340.00$   
 $ho = 340.00$   
 $bi2 = 462400.00$   
 $psh_{min} = \text{Min}(psh_x, psh_y) = 0.00392699$

---

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

---

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

---

$s = 100.00$   
 $fy_{we} = 555.5556$   
 $f_{ce} = 20.00$   
 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  
 $lo/lou_{min} = lb/ld = 0.30$   
 $su1 = 0.4 * esu1_{nominal} ((5.5), TBDY) = 0.032$   
 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
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 lb/d = 0.30

Calculation of Mu1-

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 1.7976030E-005$$

$$\mu_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

The Shear\_factor is considered equal to 1 (pure moment strength)

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

$$\omega_e \text{ ((5.4c), TBDY)} = a_s e * \frac{f_{ywe}}{f_{ce}} + \text{Min}(\phi_x, \phi_y) = 0.14357935$$

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

$$\phi_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$\phi_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \cos(\beta_1) = 1.016$$

$$f_u, f = 1055.00$$

$$E_f = 64828.00$$

$$u, f = 0.015$$

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

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_i^2 = 462400.00$$

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

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

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

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

$$b_k = 400.00$$

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

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$f_{t1} = 373.4504$$

$$f_{y1} = 311.2087$$

$$su_1 = 0.00512$$

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
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 = 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 < vsy2 - 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

```

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Calculation of ratio lb/ld

-----

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{2+}$

Calculation of ultimate curvature  $\mu$  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)

$$\text{From (5.4b), TBDY: } \mu_{2+} = 0.018$$

$$\mu_{2+} \text{ ((5.4c), TBDY)} = a_{se} * \mu_{2+,min} * f_{ywe}/f_{ce} + \text{Min}(\mu_{2+,x}, \mu_{2+,y}) = 0.14357935$$

where  $\mu_{2+,x} = a_f * \mu_{2+,x}^* / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\mu_{2+,x} = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A4.4.3(6), } \mu_{2+,x} = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

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

$$\mu_{2+,y} = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A4.4.3(6), } \mu_{2+,y} = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$\mu_{2+,f} = 0.015$$

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

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$\mu_{2+,min} = \text{Min}(\mu_{2+,x}, \mu_{2+,y}) = 0.00392699$$

$$\mu_{2+,x} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$\mu_{2+,y} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

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

```

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 = 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

```

--->

$$s_u(4.9) = 0.2021744$$

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

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

Calculation of ratio  $I_b/I_d$

Inadequate Lap Length with  $I_b/I_d = 0.30$

Calculation of  $\mu_2$ -

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

$$u = 1.7976030E-005$$

$$\mu = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, \alpha) = 0.018$$

The Shear\_factor is considered equal to 1 (pure moment strength)

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

$$\mu_e((5.4c), TBDY) = \alpha * \mu_{\min} * f_{ywe}/f_{ce} + \text{Min}(\mu_x, \mu_y) = 0.14357935$$

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

$$\mu_x = 0.11712639$$

$$\alpha = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$\mu_y = 0.11712639$$

$$\alpha = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$\mu_{f} = 0.015$$

$$\alpha_e((5.4d), TBDY) = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

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

$$\mu_{\min,x}(5.4d) = 0.00392699$$

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

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

$$b_k = 400.00$$

$$\mu_{\min,y}(5.4d) = 0.00392699$$



Ash = Astir\*ns = 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

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

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

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

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

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$\mu_u(4.9) = 0.2021744$

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

$u = \mu_u(4.1) = 1.7976030E-005$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

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

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)

$M/Vd = 2.00$

$\mu_u = 4.6307395E-012$

$\mu_u = 4.2515079E-047$

$d = 0.8 * h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

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:  $\theta = \theta_1 + 90^\circ = 90.00$

$V_f = \min(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:

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

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

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

$E_f = 64828.00$

$f_{fe} = 0.004$ , 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,  $V_{r2} = 524051.339$

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

$V_{Col0} = 524051.339$

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

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

orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$  (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,  $\phi = 0.95$

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  $135^\circ$ )

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,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

Bending Moment,  $M = 7.3941089E-010$

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:  $A_{sl,t} = 829.3805$

-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,  $Db_L = 18.66667$

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  $pt = 0.00580799$

$pc = 0.00580799$

$pv = 0.00281599$

$N = 5924.669$

$b = 400.00$

$\mu = 0.12044818$   
 $y_{comp} = 1.8620196E-005$   
 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,  $t_f = N_L * t * \cos(b_1) = 1.016$   
 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  $I_b/I_d$

Inadequate Lap Length with  $I_b/I_d = 0.30$

- Calculation of  $p$  -

From table 10-8:  $p = 0.042$

with:

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

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.

$N_{UD} = 5924.669$

$A_g = 160000.00$

$f_{cE} = 20.00$

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

$p_l = \text{Area\_Tot\_Long\_Rein} / (b * d) = 0.01443197$

$b = 400.00$

$d = 357.00$

$f_{cE} = 20.00$

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

At local axis: 2

Integration Section: (a)

## Calculation No. 11

column C1, Floor 1

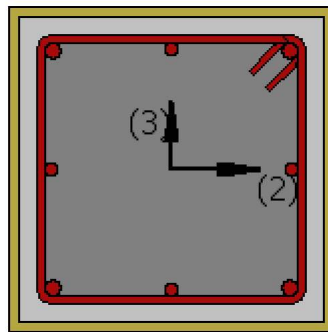
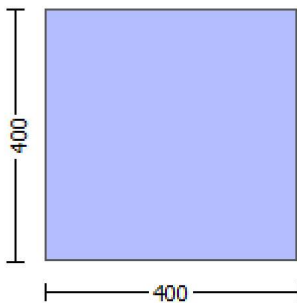
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: Start

Local Axis: (3)



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

At local axis: 3

Integration Section: (a)

Section Type: rcrs

Constant Properties

Knowledge Factor,  $\gamma = 0.95$

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  $\gamma$  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  $135^\circ$ )

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,  $D_{bL,ten} = 18.66667$

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) =  $k_n V_{Col} = 468849.376$

$V_{Col} = 468849.376$

$k_n = 1.00$

displacement\_ductility\_demand = 0.00

NOTE: In expression (10-3) ' $V_s = A_v f_y d/s$ ' 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  $f'_c \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 7.3941089E-010$

$V_u = 1.9223267E-013$

$d = 0.8 \cdot h = 320.00$

$N_u = 5924.669$

$A_g = 160000.00$

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  $Col = 1.00$

$s/d = 0.3125$

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

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

total thickness per orientation,  $tf1 = NL*t/NoDir = 1.016$   
 $dfv = d$  (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  $\delta / y$

- Calculation of  $\delta / y$  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  $\delta / y$  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  $pt = 0.00580799$   
 $pc = 0.00580799$   
 $pv = 0.00281599$   
 $N = 5924.669$   
 $b = 400.00$   
 $" = 0.12044818$   
 $y_{comp} = 1.8620196E-005$   
 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:  $ka = 0.56708553$   
 $g = pt + pc + pv = 0.01443197$   
 $rc = 40.00$   
 $Ae/Ac = 0.56708553$   
 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  $I_b/I_d$

Inadequate Lap Length with  $I_b/I_d = 0.30$

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

At local axis: 3

Integration Section: (a)

## Calculation No. 12

column C1, Floor 1

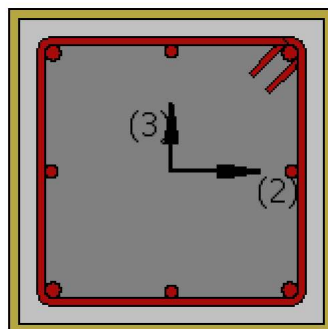
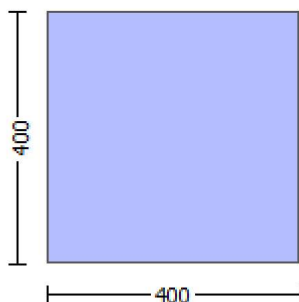
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

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,  $ε_{fu}$  = 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 $\mu_{u1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\phi_u = 1.7976030E-005$

$$\mu_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \mu_c) = 0.018$$

The Shear\_factor is considered equal to 1 (pure moment strength)

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

$$\mu_{ue} ((5.4c), \text{TB DY}) = \alpha s e * \mu_{u,min} * f_{ywe} / f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.14357935$$

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

$$\mu_{fx} = 0.11712639$$

$$\alpha f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

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

$$\mu_{fy} = 0.11712639$$

$$\alpha f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$\alpha s e ((5.4d), \text{TB DY}) = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_i^2 = 462400.00$$

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

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

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

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

$$b_k = 400.00$$

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

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \mu_c = 0.00411734$$

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

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$f_{t1} = 373.4504$$

$$f_{y1} = 311.2087$$

$$s_{u1} = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

$$\text{Shear\_factor} = 1.00$$

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

```

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/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 = 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  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.7976030E-005$$

$$Mu = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, \alpha) = 0.018$$

The Shear\_factor is considered equal to 1 (pure moment strength)

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

$$\mu_e ((5.4c), TBDY) = \alpha * \mu_{\min} * f_{ywe} / f_{ce} + \text{Min}(\mu_x, \mu_y) = 0.14357935$$

where  $\mu = \alpha * \mu_{\min} * f_{ywe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\mu_x = 0.11712639$$

$$\alpha = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$\mu_y = 0.11712639$$

$$\alpha = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$\mu_{f} = 0.015$$

$$\alpha_e ((5.4d), TBDY) = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

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

$$\mu_{\min,x} (5.4d) = 0.00392699$$

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

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

$$b_k = 400.00$$

$$\mu_{\min,y} (5.4d) = 0.00392699$$

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.0012967$$

```

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/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 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,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 Min(1,1.25*(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

```

$$\begin{aligned} \mu_u &= M_{Rc} (4.14) = 1.1045E+008 \\ u &= s_u (4.1) = 1.7976030E-005 \end{aligned}$$

Calculation of ratio  $I_b/I_d$

Inadequate Lap Length with  $I_b/I_d = 0.30$

Calculation of  $\mu_{u2+}$

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$$\begin{aligned} u &= 1.7976030E-005 \\ \mu_u &= 1.1045E+008 \end{aligned}$$

with full section properties:

$$\begin{aligned} b &= 400.00 \\ d &= 357.00 \\ d' &= 43.00 \\ v &= 0.00207526 \\ N &= 5926.932 \\ f_c &= 20.00 \\ c_o (5A.5, TBDY) &= 0.002 \end{aligned}$$

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)

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

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

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

$$\begin{aligned} f_x &= 0.11712639 \\ a_f &= 0.57333333 \end{aligned}$$

$$\begin{aligned} b &= 400.00 \\ h &= 400.00 \end{aligned}$$

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

$$b_w = 400.00$$

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

$$\begin{aligned} f_y &= 0.11712639 \\ a_f &= 0.57333333 \end{aligned}$$

$$\begin{aligned} b &= 400.00 \\ h &= 400.00 \end{aligned}$$

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,  $t_f = N L^* t \cos(b_1) = 1.016$

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

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

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

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

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

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

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,  $n_s = 2.00$

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  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , 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/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



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

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

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  $I_b/I_d$

Inadequate Lap Length with  $I_b/I_d = 0.30$

Calculation of  $M_{u2}$ -

Calculation of ultimate curvature  $\kappa_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.7976030E-005$$

$$M_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

The Shear\_factor is considered equal to 1 (pure moment strength)

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

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

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

$$\kappa_{fx} = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A4.4.3(6), } p_f = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

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

$$\kappa_{fy} = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A4.4.3(6), } p_f = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

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

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(\theta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

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

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

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

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  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , 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/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:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

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

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

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

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

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

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

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 Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 524051.339$

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

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

$$V_{Col0} = 524051.339$$

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

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)

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

$$M/Vd = 2.00$$

$$\mu_u = 1.8671199E-011$$

$$V_u = 6.9434686E-031$$

$$d = 0.8 * h = 320.00$$

$$N_u = 5926.932$$

$$A_g = 160000.00$$

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

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

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

$$s/d = 0.3125$$

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

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

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

In (11.3)  $\sin \theta + \cos \theta$  is replaced with  $(\cot \theta + \cot \alpha) \sin \alpha$  which is more a generalised expression, where  $\theta$  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  $\alpha_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

$$\text{orientation 1: } \theta = \theta_1 + 90^\circ = 90.00$$

$$V_f = \min(|V_f(45, \theta_1)|, |V_f(-45, \alpha_1)|), \text{ with:}$$

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

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

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

$$E_f = 64828.00$$

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

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

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

bw = 400.00

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

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

$V_{Col0} = 524051.339$

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

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' 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)

$M/Vd = 2.00$

$\mu_u = 1.8671199E-011$

$\mu_v = 6.9434686E-031$

$d = 0.8 * h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

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

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

orientation 1:  $\theta_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:

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

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

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

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

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,  $= 0.95$

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:  $As_t = 0.00$ 
  -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
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 1.1045E+008$ 
 $\mu_{u1+} = 1.1045E+008$ , 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  $\mu_{u1+}$ 
-----

Calculation of ultimate curvature  $\mu_u$  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 A4.4.3(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 A4.4.3(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

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00392699$

$psh_x (5.4d) = 0.00392699$

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

$fy_{we} = 555.5556$

$f_{ce} = 20.00$

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

$l_o/l_{ou,min} = l_b/l_d = 0.30$   
 $su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$   
 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  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , 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  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , 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  
 $l_o/l_{ou,min} = l_b/l_d = 0.30$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fsv = fs = 311.2087$   
 with  $Esv = Es = 200000.00$   
 $1 = Asl_{ten}/(b * d) * (fs_1/f_c) = 0.09037478$   
 $2 = Asl_{com}/(b * d) * (fs_2/f_c) = 0.09037478$   
 $v = Asl_{mid}/(b * d) * (fsv/f_c) = 0.04381808$

and confined core properties:

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

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 Mu1-

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 1.7976030E-005$$

$$M_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$\nu = 0.00207526$$

$$N = 5926.932$$

$$f_{ct} = 20.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_{cc}) = 0.018$$

The Shear\_factor is considered equal to 1 (pure moment strength)

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

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

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

$$\phi_{fx} = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$\phi_{fy} = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \cos(\beta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$\phi_{u,f} = 0.015$$

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

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

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

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

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

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

$$b_k = 400.00$$

$$\phi_{sh,y} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

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

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



```

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 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 = 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<sub>d</sub>

Inadequate Lap Length with lb/l<sub>d</sub> = 0.30

Calculation of Mu<sub>2+</sub>

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<sub>c</sub> = 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 stirrups, ns = 2.00  
bk = 400.00

s = 100.00  
fywe = 555.5556  
fce = 20.00

From ((5A.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  $I_b/I_d$

Inadequate Lap Length with  $I_b/I_d = 0.30$

Calculation of  $M_{u2}$ -

Calculation of ultimate curvature  $\kappa_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.7976030E-005$$

$$M_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

The Shear\_factor is considered equal to 1 (pure moment strength)

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

$$\omega_{se}((5.4c), TBDY) = \alpha_{se} * \omega_{sh,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$$

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

$$f_x = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$f_y = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b1) = 1.016$$

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

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

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 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

$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.04381808$   
 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  
 --->  
 $\mu (4.9) = 0.2021744$   
 $\mu = \mu_{Rc} (4.14) = 1.1045E+008$   
 $u = \mu (4.1) = 1.7976030E-005$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

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

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)

$M/Vd = 2.00$

$\mu_u = 4.6307395E-012$

$V_u = 4.2515079E-047$

$d = 0.8 * h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

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  $\phi_{col} = 1.00$

$s/d = 0.3125$

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

$f = 0.95$ , 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:  $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \min(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , 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:  $V_s + V_f \leq 380269.701$   
 $bw = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 524051.339$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$   
 $V_{Col0} = 524051.339$   
 $knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' 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)  
 $M/Vd = 2.00$   
 $\mu_u = 4.6307395E-012$   
 $\nu_u = 4.2515079E-047$   
 $d = 0.8 * h = 320.00$   
 $N_u = 5926.932$   
 $A_g = 160000.00$   
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  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:  
total thickness per orientation,  $t_{f1} = NL * t / NoDir = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 357.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
with  $f_u = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 380269.701$   
 $bw = 400.00$

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,  $\phi = 0.95$   
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  $135^\circ$ )  
 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,  $\epsilon_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i: 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -1.6965E+007$   
 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:  $A_{st,com} = 829.3805$   
     -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  $u_{,R} = u = 0.04534246$   
 $u = y + p = 0.04772891$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00572891$  ((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  $y$  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  $fc^* (12.3, (ACI 440)) = 21.65599$   
 $fc = 20.00$   
 $fl = 0.93147527$   
 $b = 400.00$   
 $h = 400.00$   
 $Ag = 160000.00$   
 From (12.9), ACI 440:  $ka = 0.56708553$   
 $g = pt + pc + pv = 0.01443197$   
 $rc = 40.00$   
 $Ae/Ac = 0.56708553$   
 Effective FRP thickness,  $tf = NL * t * Cos(b1) = 1.016$   
 effective strain from (12.5) and (12.12),  $efe = 0.004$   
 $fu = 0.01$   
 $Ef = 64828.00$   
 $Ec = 21019.039$   
 $y = 0.2789878$   
 $A = 0.01432011$   
 $B = 0.00808514$   
 with  $Es = 200000.00$

Calculation of ratio  $lb/ld$

Inadequate Lap Length with  $lb/ld = 0.30$

- Calculation of  $p$  -

From table 10-8:  $p = 0.042$

with:

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

shear control ratio  $VyE/VCoIE = 0.14050197$

$d = 357.00$

$s = 0.00$

$t = Av / (bw * s) + 2 * tf / bw * (ffe / fs) = 0.00$

$Av = 157.0796$ , 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.

$NUD = 5924.669$

$Ag = 160000.00$

$fcE = 20.00$

$fytE = fytE = 0.00$

$pl = Area\_Tot\_Long\_Rein / (b * d) = 0.01443197$

$b = 400.00$

$d = 357.00$

$fcE = 20.00$

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

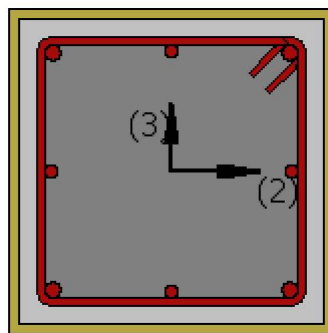
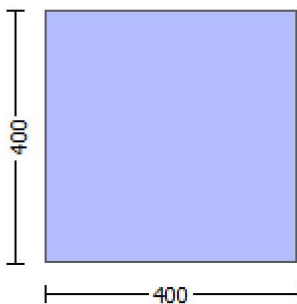
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

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  $\gamma$  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,  $M_a = -1.6965E+007$

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  $V_R = V_n = 445406.907$

$V_n ((10.3), ASCE 41-17) = knl * V_{Col0} = 468849.376$

$V_{Col} = 468849.376$

$knl = 1.00$

$displacement\_ductility\_demand = 0.33029499$

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)

$M/V_d = 2.00$

$M_u = 0.16676193$

$V_u = 5652.966$

$d = 0.8 * h = 320.00$

$N_u = 5924.669$

$A_g = 160000.00$

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  $(\cot \theta + \cot \alpha) \sin \alpha$  which is more a generalised expression, where  $\theta$  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  $\alpha_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L * t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 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:  $V_s + V_f \leq 340123.561$   
 $b_w = 400.00$

displacement ductility demand is calculated as  $\delta / y$

- Calculation of  $\delta / y$  for END B -  
 for rotation axis 3 and integ. section (b)

From analysis, chord rotation  $\theta = 0.00018915$   
 $y = (M_y * L_s / 3) / E_{eff} = 0.00057268$  ((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:  $E_{eff} = \text{factor} * E_c * I_g = 1.3452E+013$   
 $\text{factor} = 0.30$   
 $A_g = 160000.00$   
 $f_c' = 20.00$   
 $N = 5924.669$   
 $E_c * I_g = 4.4841E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta / y$  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)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 248.9669$   
 $d = 357.00$   
 $y = 0.28100816$   
 $A = 0.01459861$   
 $B = 0.00825178$   
 with  $p_t = 0.00580799$   
 $p_c = 0.00580799$   
 $p_v = 0.00281599$   
 $N = 5924.669$   
 $b = 400.00$   
 $\alpha = 0.12044818$   
 $y_{comp} = 1.8620196E-005$   
 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,  $t_f = N_L * t * \cos(b1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 21019.039$   
 $y = 0.2789878$   
 $A = 0.01432011$   
 $B = 0.00808514$

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

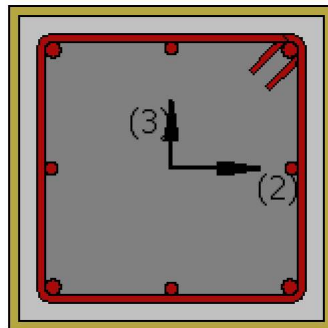
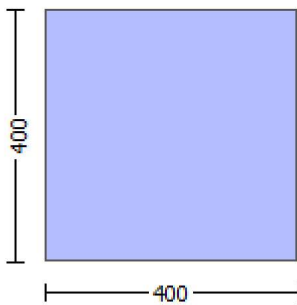
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\mu$  )

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,  $N_{oDir} = 1$ 
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:  $A_{slt} = 0.00$ 
  -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
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 1.1045E+008$ 
 $\mu_{u1+} = 1.1045E+008$ , 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

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Calculation of  $\mu_{u1+}$ 
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```

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 1.7976030E-005$$

$$\mu_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

The Shear\_factor is considered equal to 1 (pure moment strength)

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

$$\omega_e \text{ ((5.4c), TBDY)} = a_{se} * \frac{sh_{min} * f_{ywe}}{f_{ce}} + \text{Min}(\phi_x, \phi_y) = 0.14357935$$

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

$$\phi_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$\phi_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \cos(\beta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

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

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

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

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

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

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

$$b_k = 400.00$$

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

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$f_{t1} = 373.4504$$

$$f_{y1} = 311.2087$$

$$su_1 = 0.00512$$

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
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 = 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

```

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Calculation of ratio lb/ld

-----



Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{u1}$ -

Calculation of ultimate curvature  $\mu_u$  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)

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

$$\mu_{ue} \text{ ((5.4c), TBDY)} = a_{se} * \mu_{u,min} * f_{ywe}/f_{ce} + \text{Min}(\mu_{ux}, \mu_{uy}) = 0.14357935$$

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

$$\mu_{ux} = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A4.4.3(6), } \mu_{pf} = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

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

$$\mu_{uy} = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A4.4.3(6), } \mu_{pf} = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$\mu_{u,f} = 0.015$$

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

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

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

$$\mu_{psh,x} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$\mu_{psh,y} \text{ (5.4d)} = 0.00392699$$

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

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

```

c = 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 = 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  $I_b/I_d$

Inadequate Lap Length with  $I_b/I_d = 0.30$

Calculation of  $M_{u2+}$

Calculation of ultimate curvature  $\kappa_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.7976030E-005$$

$$M_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

The Shear\_factor is considered equal to 1 (pure moment strength)

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

$$\kappa_{ue}((5.4c), TBDY) = \alpha_{se} * \kappa_{u,min} * f_{ywe}/f_{ce} + \text{Min}(\kappa_{fx}, \kappa_{fy}) = 0.14357935$$

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

$$\kappa_{fx} = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$\kappa_{fy} = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

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

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

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

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

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

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

$$b_k = 400.00$$

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

Ash = Astir\*ns = 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

$c = \text{confinement factor} = 1.21173$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1160777$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1160777$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0562801$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

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

$\mu_u (4.9) = 0.2021744$   
 $\mu_u = M_{Rc} (4.14) = 1.1045E+008$   
 $u = \mu_u (4.1) = 1.7976030E-005$

Calculation of ratio  $I_b/I_d$

Inadequate Lap Length with  $I_b/I_d = 0.30$

Calculation of  $\mu_{u2}$ -

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.7976030E-005$   
 $\mu_u = 1.1045E+008$

with full section properties:

$b = 400.00$   
 $d = 357.00$   
 $d' = 43.00$   
 $v = 0.00207526$   
 $N = 5926.932$   
 $f_c = 20.00$   
 $\alpha_{co} (5A.5, TBDY) = 0.002$   
 Final value of  $\mu_{cu}$ :  $\mu_{cu}^* = \text{shear\_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.018$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\mu_{cu} = 0.018$   
 $\mu_{we} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$   
 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),  $p_f = 2t_f/bw = 0.00508$   
 $bw = 400.00$   
 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,  $t_f = N L * t * \cos(b1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $\alpha_{se} ((5.4d), TBDY) = 0.24250288$   
 $b_o = 340.00$   
 $h_o = 340.00$   
 $b_{i2} = 462400.00$

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

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

$$Ash = Astir*ns = 78.53982$$

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

$$bk = 400.00$$

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

$$Ash = Astir*ns = 78.53982$$

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

$$bk = 400.00$$

$$s = 100.00$$

$$fywe = 555.5556$$

$$fce = 20.00$$

$$\text{From } ((5A5), \text{TB DY}), \text{TB DY: } cc = 0.00411734$$

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

$$y1 = 0.0012967$$

$$sh1 = 0.0044814$$

$$ft1 = 373.4504$$

$$fy1 = 311.2087$$

$$su1 = 0.00512$$

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

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

$$su1 = 0.4*esu1\_nominal ((5.5), \text{TB DY}) = 0.032$$

From table 5A.1, TB DY: 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, TB DY.

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

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

$$su2 = 0.4*esu2\_nominal ((5.5), \text{TB DY}) = 0.032$$

From table 5A.1, TB DY: 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, TB DY.

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

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

$$suv = 0.4*esuv\_nominal ((5.5), \text{TB DY}) = 0.032$$

From table 5A.1, TB DY: esuv\_nominal = 0.08,

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

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TB DY.

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

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

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

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

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

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

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 Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 524051.339$

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

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

$$V_{Col0} = 524051.339$$

$k_{nl} = 1$  (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)

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

$$M/Vd = 2.00$$

$$M_u = 1.8671199E-011$$

$$V_u = 6.9434686E-031$$

$$d = 0.8 * h = 320.00$$

$$N_u = 5926.932$$

$$A_g = 160000.00$$

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  $Col = 1.00$

$$s/d = 0.3125$$

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

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

$w_f/s_f = 1$  (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.

$$\text{orientation 1: } \theta = \theta_1 + 90^\circ = 90.00$$

$$V_f = \min(|V_f(45, \theta_1)|, |V_f(-45, a_1)|), \text{ with:}$$

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

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

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

$$E_f = 64828.00$$

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

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)  
 $M/Vd = 2.00$   
 $\mu_u = 1.8671199E-011$   
 $\nu_u = 6.9434686E-031$   
 $d = 0.8 * h = 320.00$   
 $N_u = 5926.932$   
 $A_g = 160000.00$   
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  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , 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: 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  $135^\circ$ )

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,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = 4.2515079E-047$

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:  $As_{l,mid} = 402.1239$

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

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

$\mu_{u1+} = 1.1045E+008$ , 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

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

$\mu_{u2+} = 1.1045E+008$ , 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  $\mu_{u1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 1.7976030E-005$$

$$M_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

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

The Shear\_factor is considered equal to 1 (pure moment strength)

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

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

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

$$\phi_{fx} = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$\phi_{fy} = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

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

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

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

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

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

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

$$b_k = 400.00$$

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

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$ft_1 = 373.4504$$

$$fy_1 = 311.2087$$

$$su_1 = 0.00512$$

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  
 $l_o/l_{ou,min} = l_b/l_d = 0.30$   
 $su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,  
For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
with  $fs_1 = fs = 311.2087$   
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  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
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  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , 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  
 $l_o/l_{ou,min} = l_b/l_d = 0.30$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
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  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
with  $fsv = fs = 311.2087$   
with  $Esv = Es = 200000.00$   
 $1 = Asl_{ten}/(b * d) * (fs_1/f_c) = 0.09037478$   
 $2 = Asl_{com}/(b * d) * (fs_2/f_c) = 0.09037478$   
 $v = Asl_{mid}/(b * d) * (fsv/f_c) = 0.04381808$   
and confined core properties:  
 $b = 340.00$   
 $d = 327.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 24.23468$   
 $cc (5A.5, TBDY) = 0.00411734$   
 $c = \text{confinement factor} = 1.21173$   
 $1 = Asl_{ten}/(b * d) * (fs_1/f_c) = 0.1160777$   
 $2 = Asl_{com}/(b * d) * (fs_2/f_c) = 0.1160777$   
 $v = Asl_{mid}/(b * d) * (fsv/f_c) = 0.0562801$   
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  $\mu_{u1}$ -

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$$\mu_u = 1.7976030E-005$$

$$\mu_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u = \text{shear\_factor} * \text{Max}(c_u, c_o) = 0.018$$

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)

$$f_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$f_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

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

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

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

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

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

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

$$b_k = 400.00$$

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

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

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

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

From ((5A.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.  
 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  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , 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  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , 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:  
 $b = 340.00$   
 $d = 327.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 24.23468$   
 $cc (5A.5, TBDY) = 0.00411734$   
 $c = \text{confinement factor} = 1.21173$   
 $1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.1160777$   
 $2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.1160777$   
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.0562801$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - 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  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.7976030E-005$$

$$M_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \alpha: \alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.018$$

The Shear\_factor is considered equal to 1 (pure moment strength)

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

$$\alpha_e((5.4c), TBDY) = \alpha * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(\alpha_x, \alpha_y) = 0.14357935$$

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

$$\alpha_x = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A4.4.3(6), } p_f = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

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

$$\alpha_y = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A4.4.3(6), } p_f = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$\alpha_e((5.4d), TBDY) = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

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

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

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

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

$$b_k = 400.00$$

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/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  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , 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/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

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

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

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

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

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

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - 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  $Mu2$ -

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

$$u = 1.7976030E-005$$

$$Mu = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$fc = 20.00$$

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

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

The Shear\_factor is considered equal to 1 (pure moment strength)

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

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

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

$$fx = 0.11712639$$

$$af = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$fy = 0.11712639$$

$$af = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$bw = 400.00$$

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

$$R = 40.00$$

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

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase((5.4d), TBDY) = 0.24250288$$

$$bo = 340.00$$

$$ho = 340.00$$



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 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

--->

$$s_u (4.9) = 0.2021744$$

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

$$u = s_u (4.1) = 1.7976030E-005$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of 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).

$$= 1 \text{ (normal-weight concrete)}$$

$$f'_c = 20.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$M_u = 4.6307395E-012$$

$$V_u = 4.2515079E-047$$

$$d = 0.8 * h = 320.00$$

$$N_u = 5926.932$$

$$A_g = 160000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = 223402.144$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

$$V_s \text{ is multiplied by } Col = 1.00$$

$$s/d = 0.3125$$

$$V_f ((11-3)-(11.4), ACI 440) = 188111.148$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$$w_f/s_f = 1 \text{ (FRP strips adjacent to one another).}$$

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.

$$\text{orientation 1: } 1 = b_1 + 90^\circ = 90.00$$

$$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = N_L * t / N_{oDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 357.00$$

$$f_{fe} ((11-5), ACI 440) = 259.312$$

$$E_f = 64828.00$$

$f_e = 0.004$ , 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) =  $knl * V_{Col0}$   
 $V_{Col0} = 524051.339$   
 $knl = 1$  (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)  
 $f_c' = 20.00$ , 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  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:  
total thickness per orientation,  $t_{f1} = NL * t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) =  $357.00$   
 $f_{fe}$  ((11-5), ACI 440) =  $259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
with  $f_u = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 380269.701$   
 $bw = 400.00$

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: rcrcs

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  $135^\circ$ )  
 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,  $\epsilon_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i: 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -1.6233527E-010$   
 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,  $Db_L = 18.66667$

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
    " = 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: 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 = 0.2789878
    A = 0.01432011
    B = 0.00808514
    with Es = 200000.00

```

Calculation of ratio  $I_b/I_d$

Inadequate Lap Length with  $I_b/I_d = 0.30$

- Calculation of  $p$  -

From table 10-8:  $p = 0.042$

with:

- Columns not controlled by inadequate development or splicing along the clear height because  $I_b/I_d \geq 1$   
 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.

$NUD = 5924.669$

$Ag = 160000.00$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 0.00$

$pl = \text{Area\_Tot\_Long\_Rein}/(b*d) = 0.01443197$

$b = 400.00$

$d = 357.00$

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 15

column C1, Floor 1

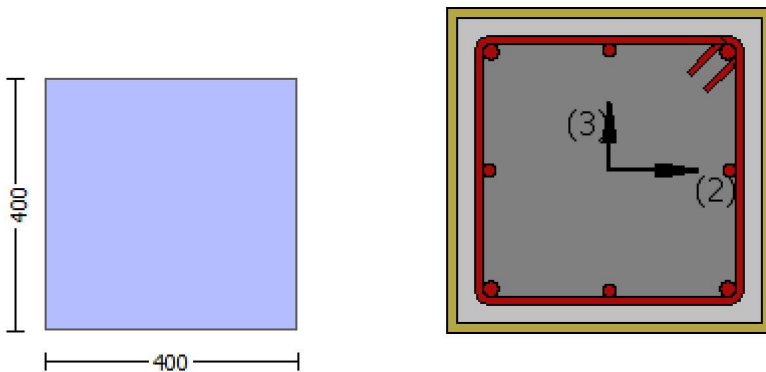
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcrs

Constant Properties

Knowledge Factor,  $\gamma = 0.95$

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  $\gamma$  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,  $NoDir = 1$   
 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,  $M_a = 7.3941089E-010$   
 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:  $As_t = 0.00$   
   -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  $V_R = V_n = 445406.907$   
 $V_n ((10.3), ASCE 41-17) = knl * V_{ColO} = 468849.376$   
 $V_{Col} = 468849.376$   
 $knl = 1.00$   
 $displacement\_ductility\_demand = 0.00$

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).

$\beta = 1$  (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  
 $w_f/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin \theta + \cos \theta$  is replaced with  $(\cot \theta + \cot \alpha) \sin \alpha$  which is more a generalised expression,  
 where  $\theta$  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  $\theta$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$  (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  $\delta / y$

- Calculation of  $\delta / y$  for END B -

for rotation axis 2 and integ. section (b)

From analysis, chord rotation  $\theta = 1.1274962E-020$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00286339$  ((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:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 1.3452E+013$

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  $\delta$  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,  $t_f = N_L \cdot t \cdot \cos(\theta_1) = 1.016$

effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 21019.039$

$y = 0.2789878$



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

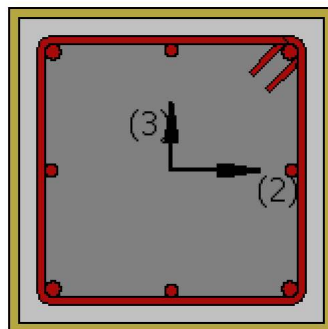
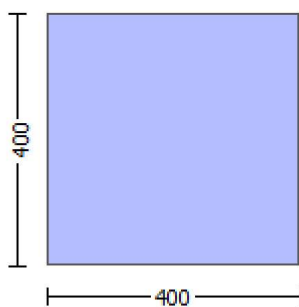
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( u)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcrs

Constant Properties

Knowledge Factor,  $\gamma = 0.95$

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  $135^\circ$ )

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,  $\epsilon_{fu} = 0.01$

Number of directions,  $N_{oDir} = 1$

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### ----- Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = -6.9434686E-031$

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:  $As_{c,com} = 829.3805$

-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

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.1045E+008$

$Mu_{1+} = 1.1045E+008$ , 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  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.7976030E-005$$

$$Mu = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

$$\alpha_{co} \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.018$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.018$$

$$\phi_{we} \text{ ((5.4c), TBDY)} = \alpha_{se} * \phi_{sh,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.14357935$$

where  $\phi_f = \alpha_f * \phi_f' * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$\phi_{fy} = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TBDY)} = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00392699$$

$$\phi_{sh,x} \text{ (5.4d)} = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$\phi_{sh,y} \text{ (5.4d)} = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.00411734$$

$$c = \text{confinement factor} = 1.21173$$

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$f_{t1} = 373.4504$$

$$f_{y1} = 311.2087$$

$$su_1 = 0.00512$$

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  
 $l_o/l_{ou,min} = l_b/l_d = 0.30$   
 $su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,  
 For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
 characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs_1 = fs = 311.2087$   
 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  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , 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  
 $l_o/l_{ou,min} = l_b/l_d = 0.30$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fsv = fs = 311.2087$   
 with  $Es_v = Es = 200000.00$   
 $1 = Asl_{ten}/(b*d) * (fs_1/f_c) = 0.09037478$   
 $2 = Asl_{com}/(b*d) * (fs_2/f_c) = 0.09037478$   
 $v = Asl_{mid}/(b*d) * (fsv/f_c) = 0.04381808$   
 and confined core properties:  
 $b = 340.00$   
 $d = 327.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 24.23468$   
 $cc (5A.5, TBDY) = 0.00411734$   
 $c = \text{confinement factor} = 1.21173$   
 $1 = Asl_{ten}/(b*d) * (fs_1/f_c) = 0.1160777$   
 $2 = Asl_{com}/(b*d) * (fs_2/f_c) = 0.1160777$   
 $v = Asl_{mid}/(b*d) * (fsv/f_c) = 0.0562801$   
 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  $\mu_{u1}$ -

Calculation of ultimate curvature  $\mu_u$  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)

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$$

where  $f = a_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$f_y = 0.11712639$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00392699$$

$$p_{sh,x} \text{ (5.4d)} = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

```

fce = 20.00
From ((5A.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 = 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)

```

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $\mu_u (4.9) = 0.2021744$   
 $\mu_u = M_{Rc} (4.14) = 1.1045E+008$   
 $u = \mu_u (4.1) = 1.7976030E-005$

Calculation of ratio  $I_b/I_d$

Inadequate Lap Length with  $I_b/I_d = 0.30$

Calculation of  $\mu_{u2+}$

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.7976030E-005$   
 $\mu_u = 1.1045E+008$

with full section properties:

$b = 400.00$   
 $d = 357.00$   
 $d' = 43.00$   
 $v = 0.00207526$   
 $N = 5926.932$

$f_c = 20.00$

$\alpha (5A.5, TBDY) = 0.002$

Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \mu_c) = 0.018$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_u = 0.018$

$\mu_u ((5.4c), TBDY) = \alpha * \mu_{u,min} * f_{ywe}/f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.14357935$

where  $\mu_{fx} = \alpha * \mu_{pf} * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\mu_{fx} = 0.11712639$

$\mu_{af} = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6),  $\mu_{pf} = 2t_f/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $f_{fe} = 804.2922$

$\mu_{fy} = 0.11712639$

$\mu_{af} = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6),  $\mu_{pf} = 2t_f/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $f_{fe} = 804.2922$

$R = 40.00$

Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{u,f} = 0.015$

$\mu_{ase} ((5.4d), TBDY) = 0.24250288$

$b_o = 340.00$

$h_o = 340.00$

$b_{i2} = 462400.00$

$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.00392699$

$\mu_{psh,x} (5.4d) = 0.00392699$

$A_{sh} = A_{stir} * n_s = 78.53982$

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/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



$f_{cc}$  (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  
 --->  
 $su$  (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  $u$  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  $cu$ :  $cu^* = shear\_factor * Max(cu, cc) = 0.018$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $cu = 0.018$

$w_e$  ((5.4c), TBDY) =  $ase * sh_{,min} * f_{ywe}/f_{ce} + Min(f_x, f_y) = 0.14357935$

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 A4.4.3(6),  $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $ff_{,e} = 804.2922$

$f_y = 0.11712639$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $ff_{,e} = 804.2922$

$R = 40.00$

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

$bo = 340.00$

$h_o = 340.00$   
 $bi2 = 462400.00$   
 $psh,min = \text{Min}(psh,x, psh,y) = 0.00392699$

$psh,x (5.4d) = 0.00392699$   
 $Ash = Astir*ns = 78.53982$   
 $No \text{ stirups}, ns = 2.00$   
 $bk = 400.00$

$psh,y (5.4d) = 0.00392699$   
 $Ash = Astir*ns = 78.53982$   
 $No \text{ stirups}, ns = 2.00$   
 $bk = 400.00$

$s = 100.00$   
 $fywe = 555.5556$   
 $fce = 20.00$   
 From ((5.A5), TBDY), TBDY:  $cc = 0.00411734$   
 $c = \text{confinement factor} = 1.21173$   
 $y1 = 0.0012967$   
 $sh1 = 0.0044814$   
 $ft1 = 373.4504$   
 $fy1 = 311.2087$   
 $su1 = 0.00512$   
 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.  
 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  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , 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  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , 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:  
 $b = 340.00$   
 $d = 327.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 24.23468$   
 $cc (5A.5, TBDY) = 0.00411734$   
 $c = \text{confinement factor} = 1.21173$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1160777$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1160777$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0562801$   
Case/Assumption: Unconfined full section - Steel rupture  
'satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
--->  
 $su (4.9) = 0.2021744$   
 $\mu_u = M_{Rc} (4.14) = 1.1045E+008$   
 $u = su (4.1) = 1.7976030E-005$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 524051.339$

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)  
 $M/Vd = 2.00$   
 $\mu_u = 1.8671199E-011$   
 $V_u = 6.9434686E-031$   
 $d = 0.8 * h = 320.00$   
 $N_u = 5926.932$   
 $A_g = 160000.00$   
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  $a$  is the angle of the crack direction (see KANEPE).  
This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
orientation 1:  $\theta = b_1 + 90^\circ = 90.00$   
 $V_f = \min(|V_f(45, \theta)|, |V_f(-45, \theta)|)$ , with:  
total thickness per orientation,  $t_{f1} = N_L * t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 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,  $V_{r2} = 524051.339$   
 $V_{r2} = V_{CoI}$  ((10.3), ASCE 41-17) =  $k_n I \cdot V_{CoI0}$   
 $V_{CoI0} = 524051.339$   
 $k_n I = 1$  (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)  
 $M/Vd = 2.00$   
 $\mu_u = 1.8671199E-011$   
 $V_u = 6.9434686E-031$   
 $d = 0.8 \cdot h = 320.00$   
 $N_u = 5926.932$   
 $A_g = 160000.00$   
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  $Col = 1.00$   
 $s/d = 0.3125$   
 $V_f$  ((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:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) =  $357.00$   
 $f_{fe}$  ((11-5), ACI 440) =  $259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
with  $f_u = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 380269.701$   
 $b_w = 400.00$

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: 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  $135^\circ$ )  
 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:  $As_{t,ten} = 829.3805$   
 -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  $\kappa_u$  according to 4.1, Biskinis/Fardis 2013:

$$\kappa_u = 1.7976030E-005$$

$$\mu_u = 1.1045E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$\nu = 0.00207526$$

$$N = 5926.932$$

$$f_c = 20.00$$

$$\alpha_{co} \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \kappa_u: \kappa_u^* = \text{shear\_factor} * \text{Max}(\kappa_u, \kappa_c) = 0.018$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \kappa_u = 0.018$$

$$\omega_{se} \text{ ((5.4c), TBDY)} = \alpha_{se} * \omega_{sh,min} * f_{ywe}/f_{ce} + \text{Min}(\omega_{fx}, \omega_{fy}) = 0.14357935$$

where  $\omega_f = \alpha_f * \rho_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\omega_{fx} = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$\omega_{fy} = 0.11712639$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 804.2922$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$\omega_{u,f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TBDY)} = 0.24250288$$

$$b_o = 340.00$$

$$h_o = 340.00$$

$$b_{i2} = 462400.00$$

$$\rho_{sh,min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.00392699$$

$$\rho_{sh,x} \text{ (5.4d)} = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$\rho_{sh,y} \text{ (5.4d)} = 0.00392699$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

$$\text{No stirups, } n_s = 2.00$$

$$b_k = 400.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \alpha_{cc} = 0.00411734$$

$$\alpha_c = \text{confinement factor} = 1.21173$$

$$\gamma_1 = 0.0012967$$

$$\omega_{sh1} = 0.0044814$$

$$f_{t1} = 373.4504$$

$$f_{y1} = 311.2087$$

```

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/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 Min(1,1.25*(lb/lb,min)^ 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,min)^ 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 Min(1,1.25*(lb/lb,min)^ 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  $\mu_{u1}$ -

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$\mu_u = 1.7976030E-005$

$\mu_u = 1.1045E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00207526$

$N = 5926.932$

$f_c = 20.00$

$\phi$  (5A.5, TBDY) = 0.002

Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \phi) = 0.018$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_u = 0.018$

$\mu_{ue}$  ((5.4c), TBDY) =  $\text{ase} * \text{sh\_min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$

where  $f = \text{af} * \text{pf} * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.11712639$

$\text{af} = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6),  $\text{pf} = 2\text{tf}/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 804.2922$

$f_y = 0.11712639$

$\text{af} = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6),  $\text{pf} = 2\text{tf}/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 804.2922$

$R = 40.00$

Effective FRP thickness,  $\text{tf} = \text{NL} * t * \text{Cos}(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{u,f} = 0.015$

$\text{ase}$  ((5.4d), TBDY) = 0.24250288

$b_o = 340.00$

$h_o = 340.00$

$b_{i2} = 462400.00$

$\text{psh\_min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.00392699$

$\text{psh}_x$  (5.4d) = 0.00392699

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups,  $n_s = 2.00$

$b_k = 400.00$

$\text{psh}_y$  (5.4d) = 0.00392699

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups,  $n_s = 2.00$

$b_k = 400.00$

$s = 100.00$



```

fywe = 555.5556
fce = 20.00
From ((5A.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 = 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

--->

$\mu_u (4.9) = 0.2021744$

$M_u = M_{Rc} (4.14) = 1.1045E+008$

$u = \mu_u (4.1) = 1.7976030E-005$

Calculation of ratio  $I_b/I_d$

Inadequate Lap Length with  $I_b/I_d = 0.30$

Calculation of  $\mu_{u2+}$

Calculation of ultimate curvature  $\mu_u$  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  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \mu_c) = 0.018$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_u = 0.018$

$\mu_{ue} ((5.4c), TBDY) = \alpha * \mu_{ue,min} * f_{ywe}/f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.14357935$

where  $f = \alpha * \mu_{ue} * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\mu_{fx} = 0.11712639$

$\alpha_f = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6),  $\mu_f = 2t_f/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $f_{fe} = 804.2922$

$\mu_{fy} = 0.11712639$

$\alpha_f = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6),  $\mu_f = 2t_f/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $f_{fe} = 804.2922$

$R = 40.00$

Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{u,f} = 0.015$

$\alpha_{se} ((5.4d), TBDY) = 0.24250288$

$b_o = 340.00$

$h_o = 340.00$

$b_{i2} = 462400.00$

$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.00392699$

$\mu_{psh,x} (5.4d) = 0.00392699$

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups,  $n_s = 2.00$

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

$d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 24.23468$   
 $cc (5A.5, TBDY) = 0.00411734$   
 $c = \text{confinement factor} = 1.21173$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1160777$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1160777$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0562801$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->

$su (4.9) = 0.2021744$   
 $Mu = MR_c (4.14) = 1.1045E+008$   
 $u = su (4.1) = 1.7976030E-005$

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  $u$  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:  $cu = 0.018$   
 $w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.14357935$   
 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),  $p_f = 2t_f/bw = 0.00508$   
 $bw = 400.00$   
 effective stress from (A.35),  $f_{fe} = 804.2922$

$f_y = 0.11712639$   
 $a_f = 0.57333333$   
 $b = 400.00$   
 $h = 400.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00508$   
 $bw = 400.00$   
 effective stress from (A.35),  $f_{fe} = 804.2922$

$R = 40.00$   
 Effective FRP thickness,  $t_f = NL * t * \text{Cos}(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $a_{se} ((5.4d), TBDY) = 0.24250288$

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,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 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,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 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  
 --->

$su (4.9) = 0.2021744$   
 $\mu_u = M_{Rc} (4.14) = 1.1045E+008$   
 $u = su (4.1) = 1.7976030E-005$

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  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $1 = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L * t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 357.00

$f_{fe} ((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , 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,  $V_{r2} = 524051.339$   
 $V_{r2} = V_{Col} ((10.3), \text{ASCE 41-17}) = k_{nl} \cdot V_{Col0}$   
 $V_{Col0} = 524051.339$   
 $k_{nl} = 1$  (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).

$= 1$  (normal-weight concrete)  
 $f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $M_u = 4.6307395E-012$   
 $V_u = 4.2515079E-047$   
 $d = 0.8 \cdot h = 320.00$   
 $N_u = 5926.932$   
 $A_g = 160000.00$   
 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  $Col = 1.00$   
 $s/d = 0.3125$   
 $V_f ((11-3)-(11.4), \text{ACI 440}) = 188111.148$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a_i = 45^\circ$  and  $a_i = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 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:  $V_s + V_f \leq 380269.701$   
 $b_w = 400.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1  
 At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1  
 At local axis: 3  
 Integration Section: (b)  
 Section Type: rcrs

Constant Properties

Knowledge Factor,  $\phi = 0.95$   
 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  $135^\circ$ )  
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,  $\epsilon_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i: 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = 0.16676193$   
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,  $Db_L = 18.66667$

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) fy = Min(fy, 1.25*fy*(lb/ld)^ 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: 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 = 0.2789878
A = 0.01432011
B = 0.00808514
with Es = 200000.00

```

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Calculation of ratio lb/ld

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Inadequate Lap Length with lb/ld = 0.30

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- Calculation of p -

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From table 10-8: p = 0.042

with:

- Columns not controlled by inadequate development or splicing along the clear height because lb/ld >= 1  
shear control ratio VyE/VColOE = 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 = 5924.669

Ag = 160000.00

fcE = 20.00

fytE = fyle = 0.00

pl = Area\_Tot\_Long\_Rein/(b\*d) = 0.01443197

b = 400.00

d = 357.00

fcE = 20.00

-----

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (b)

