

# Detailed Member Calculations

**Units: N&mm**

**Regulation: ASCE 41-17**

## Calculation No. 1

column C1, Floor 1

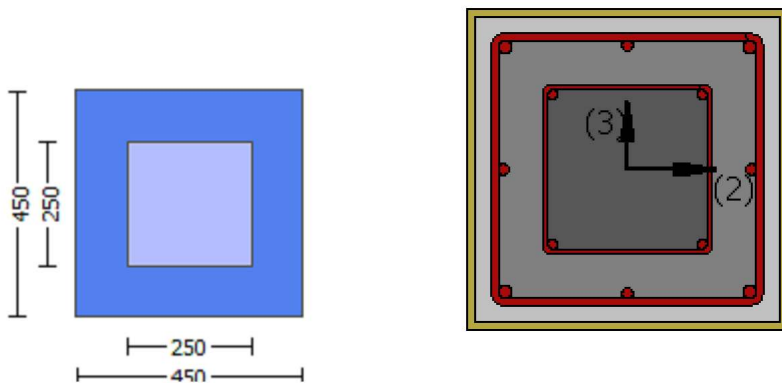
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
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  $\mu_y$  for displacement ductility demand,  
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as  
Deformation-Controlled Action (Table C7-1, ASCE 41-17).  
Jacket  
New material: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material: Steel Strength,  $f_s = f_{sm} = 555.56$   
Existing Column  
Existing material: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material: Steel Strength,  $f_s = f_{sm} = 444.44$   
#####  
External Height,  $H = 450.00$   
External Width,  $W = 450.00$   
Internal Height,  $H = 250.00$   
Internal Width,  $W = 250.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = l_b = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $\epsilon_{fu} = 0.01$   
Number of directions,  $NoDir = 1$   
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,  $M_a = -2.3098E+007$   
Shear Force,  $V_a = -7697.601$   
EDGE -B-  
Bending Moment,  $M_b = 0.06012619$   
Shear Force,  $V_b = 7697.601$   
BOTH EDGES  
Axial Force,  $F = -7503.728$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 1137.257$   
-Compression:  $As_c = 1539.38$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten} = 1137.257$   
-Compression:  $As_{l,com} = 1137.257$   
-Middle:  $As_{l,mid} = 402.1239$   
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = *V_n = 365324.682$   
 $V_n ((10.3), ASCE 41-17) = knl * V_{Co10} = 429793.743$

VCol = 429793.743  
knl = 1.00  
displacement\_ductility\_demand = 0.03746071

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)  
Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 22.22222$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
M/Vd = 4.00  
Mu = 2.3098E+007  
Vu = 7697.601  
d = 0.8\*h = 360.00  
Nu = 7503.728  
Ag = 202500.00  
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 129852.496  
where:  
Vs1 = 62831.853 is calculated for jacket, with:  
d = 360.00  
Av = 157079.633  
fy = 500.00  
s = 300.00  
Vs1 is multiplied by Col1 = 0.66666667  
s/d = 0.83333333  
Vs2 = 67020.643 is calculated for core, with:  
d = 200.00  
Av = 100530.965  
fy = 400.00  
s = 120.00  
Vs2 is multiplied by Col2 = 1.00  
s/d = 0.60  
Vf ((11-3)-(11.4), ACI 440) = 214457.247  
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:  $\alpha = b1 + 90^\circ = 90.00$   
Vf = Min(|Vf(45, 1)|, |Vf(-45, a1)|), with:  
total thickness per orientation, tf1 = NL\*t/NoDir = 1.016  
dfv = d (figure 11.2, ACI 440) = 407.00  
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 <= 507312.442  
bw = 450.00

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

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

From analysis, chord rotation  $\theta_r = 0.00024357$   
 $y = (My \cdot Ls / 3) / Eleff = 0.00650201$  ((4.29), Biskinis Phd))  
My = 1.7613E+008  
Ls = M/V (with  $Ls > 0.1 \cdot L$  and  $Ls < 2 \cdot L$ ) = 3000.708  
From table 10.5, ASCE 41\_17: Eleff = factor\*Ec\*Ig = 2.7095E+013  
factor = 0.30  
Ag = 202500.00  
Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$   
N = 7503.728  
Ec\*Ig = Ec\_jacket\*Ig\_jacket + Ec\_core\*Ig\_core = 9.0315E+013

### Calculation of Yielding Moment $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

```
y = Min( y_ten, y_com)
y_ten = 6.1806747E-006
with ((10.1), ASCE 41-17) fy = Min(fy, 1.25*fy*(lb/d)^ 2/3) = 374.3546
d = 407.00
y = 0.25591435
A = 0.0147239
B = 0.00818869
with pt = 0.00620943
pc = 0.00620943
pv = 0.0021956
N = 7503.728
b = 450.00
" = 0.10565111
y_comp = 2.2127278E-005
with fc* (12.3, (ACI 440)) = 34.40847
fc = 33.00
fl = 0.82797802
b = 450.00
h = 450.00
Ag = 202500.00
From (12.9), ACI 440: ka = 0.54261599
g = pt + pc + pv = 0.01461445
rc = 40.00
Ae/Ac = 0.54261599
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 = 26999.444
y = 0.25471862
A = 0.01452515
B = 0.00807924
with Es = 200000.00
```

### Calculation of ratio $l_b/d$

Lap Length:  $l_d/l_d, \min = 0.42476573$

$l_b = 300.00$

$l_d = 706.2717$

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

```
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 524.4464
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.98765, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.86234
Atr = Min(Atr_x, Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis
s = Max(s_external, s_internal) = 300.00
n = 12.00
```

End Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (a)

## Calculation No. 2

column C1, Floor 1

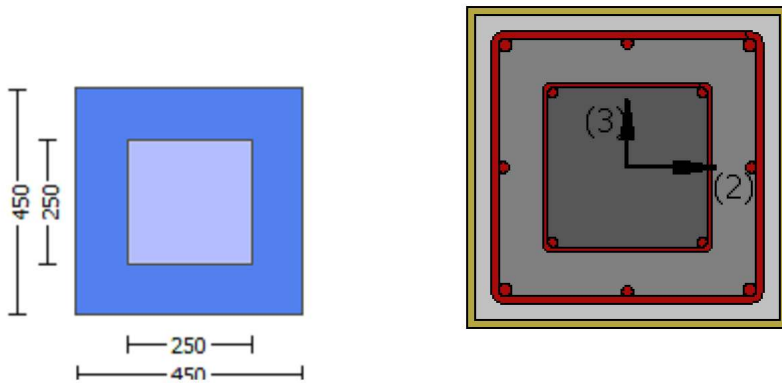
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\mu$  )

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

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

#####

External Height, H = 450.00  
External Width, W = 450.00  
Internal Height, H = 250.00  
Internal Width, W = 250.00  
Cover Thickness, c = 25.00  
Mean Confinement Factor overall section = 1.10542  
Element Length, L = 3000.00  
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o$  = 300.00  
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness, t = 1.016  
Tensile Strength,  $f_{fu}$  = 1055.00  
Tensile Modulus,  $E_f$  = 64828.00  
Elongation,  $ε_{fu}$  = 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

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Stepwise Properties  
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At local axis: 3  
EDGE -A-  
Shear Force,  $V_a$  = 2.0531359E-031  
EDGE -B-  
Shear Force,  $V_b$  = -2.0531359E-031  
BOTH EDGES  
Axial Force, F = -7506.808  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{sl,t}$  = 0.00  
-Compression:  $A_{sl,c}$  = 2676.637  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten}$  = 1137.257  
-Compression:  $A_{sl,com}$  = 1137.257  
-Middle:  $A_{sl,mid}$  = 402.1239  
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Calculation of Shear Capacity ratio ,  $V_e/V_r$  = 0.26068017  
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$   
with  
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 2.2193E+008$   
 $\mu_{u1+} = 2.2193E+008$ , 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  
 $\mu_{u1-} = 2.2193E+008$ , 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  
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 2.2193E+008$   
 $\mu_{u2+} = 2.2193E+008$ , 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  
 $\mu_{u2-} = 2.2193E+008$ , 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:

$$u = 1.9632832E-005$$

$$Mu = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01393923$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.01393923$$

$$\omega_e ((5.4c), \text{TBDY}) = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.06811101$$

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

$$\phi_{fx} = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f/bw = 0.00451556$$

$$bw = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$\phi_{fy} = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f/bw = 0.00451556$$

$$bw = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

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

$$a_{se} ((5.4d), \text{TBDY}) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$a_{se1} = 0.12623274$$

$$b_{o\_1} = 390.00$$

$$h_{o\_1} = 390.00$$

$$b_{i2\_1} = 608400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$$

$$b_{o\_2} = 242.00$$

$$h_{o\_2} = 242.00$$

$$b_{i2\_2} = 234256.00$$

$$\phi_{sh, \min} * f_{ywe} = \text{Min}(\phi_{sh, x} * f_{ywe}, \phi_{sh, y} * f_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $\phi_{sh, \min} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\phi_{sh, x} * f_{ywe} = \phi_{sh1} * f_{ywe1} + \phi_{sh2} * f_{ywe2} = 1.38262$$

$$\phi_{sh1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir\_1} * n_{s\_1} = 157.0796$$

$$\text{No stirrups, } n_{s\_1} = 2.00$$

$$h_1 = 450.00$$

$$\phi_{sh2} (\text{internal}) = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir\_2} * n_{s\_2} = 100.531$$

$$\text{No stirrups, } n_{s\_2} = 2.00$$

$$h_2 = 250.00$$

$$\phi_{sh, y} * f_{ywe} = \phi_{sh1} * f_{ywe1} + \phi_{sh2} * f_{ywe2} = 1.38262$$

$$\phi_{sh1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir\_1} * n_{s\_1} = 157.0796$$

$$\text{No stirrups, } n_{s\_1} = 2.00$$

$$h_1 = 450.00$$

$$ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$$

$$Ash2 = Astir\_2 \cdot ns\_2 = 100.531$$

$$No \text{ stirups, } ns\_2 = 2.00$$

$$h2 = 250.00$$

$$Asec = 202500.00$$

$$s1 = 300.00$$

$$s2 = 120.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

$$\text{From } ((5.A.5), \text{ TBDY}), \text{ TBDY: } cc = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$y1 = 0.00152175$$

$$sh1 = 0.0048696$$

$$ft1 = 479.7871$$

$$fy1 = 399.8226$$

$$su1 = 0.0066488$$

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

$$lo/lou, \min = lb/ld = 0.33981258$$

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

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

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

$$y1, sh1, ft1, fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 \cdot (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs1 = (fs\_jacket \cdot Asl, \text{ten, jacket} + fs\_core \cdot Asl, \text{ten, core}) / Asl, \text{ten} = 399.8226$$

$$\text{with } Es1 = (Es\_jacket \cdot Asl, \text{ten, jacket} + Es\_core \cdot Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$$

$$y2 = 0.00152175$$

$$sh2 = 0.0048696$$

$$ft2 = 479.7871$$

$$fy2 = 399.8226$$

$$su2 = 0.0066488$$

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

$$lo/lou, \min = lb/lb, \min = 0.33981258$$

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

$$\text{From table 5A.1, TBDY: } esu2\_nominal = 0.08,$$

For calculation of esu2\_nominal and y2, sh2, ft2, fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

$$y1, sh1, ft1, fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 \cdot (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs2 = (fs\_jacket \cdot Asl, \text{com, jacket} + fs\_core \cdot Asl, \text{com, core}) / Asl, \text{com} = 399.8226$$

$$\text{with } Es2 = (Es\_jacket \cdot Asl, \text{com, jacket} + Es\_core \cdot Asl, \text{com, core}) / Asl, \text{com} = 200000.00$$

$$yv = 0.00152175$$

$$shv = 0.0048696$$

$$ftv = 507.2537$$

$$fyv = 422.7114$$

$$suv = 0.0066488$$

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

$$lo/lou, \min = lb/ld = 0.33981258$$

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

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

$$\text{considering characteristic value } fsyv = fsv/1.2, \text{ from table 5.1, TBDY}$$

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

$$y1, sh1, ft1, fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 \cdot (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fsv = (fs\_jacket \cdot Asl, \text{mid, jacket} + fs\_mid \cdot Asl, \text{mid, core}) / Asl, \text{mid} = 422.7114$$

$$\text{with } Esv = (Es\_jacket \cdot Asl, \text{mid, jacket} + Es\_mid \cdot Asl, \text{mid, core}) / Asl, \text{mid} = 200000.00$$

$$1 = Asl, \text{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.0752324$$

$$2 = Asl, \text{com} / (b \cdot d) \cdot (fs2 / fc) = 0.0752324$$

$$v = Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.02812438$$

and confined core properties:

$$b = 390.00$$



$d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.09371431$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09371431$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$   
 $l_b = 300.00$   
 $l_d = 882.8396$   
 Calculation of  $l_b$ ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 655.558$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}, A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$

Calculation of  $Mu1$ -

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 1.9632832E-005$   
 $Mu = 2.2193E+008$

with full section properties:

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.00124204$   
 $N = 7506.808$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01393923$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01393923$   
 $we ((5.4c), TBDY) = ase^* sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(fx, fy) = 0.06811101$   
 where  $f = af * pf * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)  
 $fx = 0.06628267$   
 $af = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$

From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $ff,e = 881.8461$

$fy = 0.06628267$   
 $af = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $ff,e = 881.8461$

$R = 40.00$   
Effective FRP thickness,  $tf = NL*t*Cos(b1) = 1.016$   
 $fu,f = 1055.00$   
 $Ef = 64828.00$   
 $u,f = 0.015$   
 $ase ((5.4d), TBDY) = (ase1*Aext+ase2*Aint)/Asec = 0.14546167$   
 $ase1 = 0.12623274$   
 $bo\_1 = 390.00$   
 $ho\_1 = 390.00$   
 $bi2\_1 = 608400.00$   
 $ase2 = Max(ase1,ase2) = 0.18853448$   
 $bo\_2 = 242.00$   
 $ho\_2 = 242.00$   
 $bi2\_2 = 234256.00$

$psh,min*Fywe = Min(psh,x*Fywe, psh,y*Fywe) = 1.38262$   
Expression ((5.4d), TBDY) for  $psh,min*Fywe$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh\_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 1.38262$   
 $ps1$  (external) =  $(Ash1*h1/s1)/Asec = 0.00116355$   
 $Ash1 = Astir\_1*ns\_1 = 157.0796$   
No stirrups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2$  (internal) =  $(Ash2*h2/s2)/Asec = 0.00103427$   
 $Ash2 = Astir\_2*ns\_2 = 100.531$   
No stirrups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$psh\_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 1.38262$   
 $ps1$  (external) =  $(Ash1*h1/s1)/Asec = 0.00116355$   
 $Ash1 = Astir\_1*ns\_1 = 157.0796$   
No stirrups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2$  (internal) =  $(Ash2*h2/s2)/Asec = 0.00103427$   
 $Ash2 = Astir\_2*ns\_2 = 100.531$   
No stirrups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$Asec = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c =$  confinement factor = 1.10542  
 $y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $lo/lou,min = lb/d = 0.33981258$

$su1 = 0.4 \cdot esu1\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
 For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , 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, ASCE 41-17.  
 with  $fs1 = (fs\_jacket \cdot Asl\_ten\_jacket + fs\_core \cdot Asl\_ten\_core) / Asl\_ten = 399.8226$   
 with  $Es1 = (Es\_jacket \cdot Asl\_ten\_jacket + Es\_core \cdot Asl\_ten\_core) / Asl\_ten = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou, min = lb/lb, min = 0.33981258$   
 $su2 = 0.4 \cdot esu2\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
 For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs2 = (fs\_jacket \cdot Asl\_com\_jacket + fs\_core \cdot Asl\_com\_core) / Asl\_com = 399.8226$   
 with  $Es2 = (Es\_jacket \cdot Asl\_com\_jacket + Es\_core \cdot Asl\_com\_core) / Asl\_com = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou, min = lb/ld = 0.33981258$   
 $suv = 0.4 \cdot esuv\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs\_jacket \cdot Asl\_mid\_jacket + fs\_mid \cdot Asl\_mid\_core) / Asl\_mid = 422.7114$   
 with  $Esv = (Es\_jacket \cdot Asl\_mid\_jacket + Es\_mid \cdot Asl\_mid\_core) / Asl\_mid = 200000.00$   
 $1 = Asl\_ten / (b \cdot d) \cdot (fs1 / fc) = 0.0752324$   
 $2 = Asl\_com / (b \cdot d) \cdot (fs2 / fc) = 0.0752324$   
 $v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl\_ten / (b \cdot d) \cdot (fs1 / fc) = 0.09371431$   
 $2 = Asl\_com / (b \cdot d) \cdot (fs2 / fc) = 0.09371431$   
 $v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.03503353$

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

--->  
 $v < vs, y2$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.33981258$   
 $lb = 300.00$

Id = 882.8396

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

db = 16.66667

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 2.86234

Atr = Min(Atr<sub>x</sub>, Atr<sub>y</sub>) = 257.6106

where Atr<sub>x</sub>, Atr<sub>y</sub> are the sum of the area of all stirrup legs along X and Y loxal axis

s = Max(s<sub>external</sub>, s<sub>internal</sub>) = 300.00

n = 12.00

Calculation of Mu2+

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

$\phi_u = 1.9632832E-005$

Mu = 2.2193E+008

with full section properties:

b = 450.00

d = 407.00

d' = 43.00

$\nu = 0.00124204$

N = 7506.808

$f_c = 33.00$

$\phi_0$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = shear\_factor \cdot \max(\phi_u, \phi_0) = 0.01393923$

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

From (5.4b), TBDY:  $\phi_u = 0.01393923$

$\phi_{ue}$  ((5.4c), TBDY) =  $ase \cdot \phi_{u,min} \cdot f_{ywe} / f_{ce} + \min(\phi_{ux}, \phi_{uy}) = 0.06811101$

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

$\phi_{ux} = 0.06628267$

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6),  $\phi_f = 2t_f / b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$\phi_{uy} = 0.06628267$

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6),  $\phi_f = 2t_f / b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

R = 40.00

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

ase ((5.4d), TBDY) =  $(ase1 \cdot A_{ext} + ase2 \cdot A_{int}) / A_{sec} = 0.14546167$

ase1 = 0.12623274

bo<sub>1</sub> = 390.00

ho<sub>1</sub> = 390.00

bi<sub>2,1</sub> = 608400.00

$ase2 = \text{Max}(ase1, ase2) = 0.18853448$   
 $bo\_2 = 242.00$   
 $ho\_2 = 242.00$   
 $bi2\_2 = 234256.00$   
 $psh, \min * Fywe = \text{Min}(psh, x * Fywe, psh, y * Fywe) = 1.38262$   
 Expression ((5.4d), TBDY) for  $psh, \min * Fywe$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh\_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 * ns\_1 = 157.0796$   
 No stirrups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 * ns\_2 = 100.531$   
 No stirrups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$psh\_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 * ns\_1 = 157.0796$   
 No stirrups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 * ns\_2 = 100.531$   
 No stirrups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$Asec = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$

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

$lo/lou, \min = lb/ld = 0.33981258$

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

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

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs, \text{jacket} * Asl, \text{ten, jacket} + fs, \text{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 399.8226$

with  $Es1 = (Es, \text{jacket} * Asl, \text{ten, jacket} + Es, \text{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$

$y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$

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

$lo/lou, \min = lb/lb, \min = 0.33981258$

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

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs, \text{jacket} * Asl, \text{com, jacket} + fs, \text{core} * Asl, \text{com, core}) / Asl, \text{com} = 399.8226$

```

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00152175
shv = 0.0048696
ftv = 507.2537
fyv = 422.7114
suv = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258
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, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
c = confinement factor = 1.10542
1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008
u = su (4.1) = 1.9632832E-005
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.33981258
lb = 300.00
ld = 882.8396
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.98765, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.86234
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 300.00
n = 12.00
-----
-----
-----
Calculation of Mu2-
-----

```

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

$$u = 1.9632832E-005$$

$$Mu = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$\phi_0 (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01393923$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.01393923$$

$$\phi_{ue} ((5.4c), TBDY) = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.06811101$$

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

$$\phi_{fx} = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_{ff} = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$\phi_{fy} = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_{ff} = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$a_{se1} = 0.12623274$$

$$b_{o\_1} = 390.00$$

$$h_{o\_1} = 390.00$$

$$b_{i2\_1} = 608400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$$

$$b_{o\_2} = 242.00$$

$$h_{o\_2} = 242.00$$

$$b_{i2\_2} = 234256.00$$

$$\phi_{sh, \min} * f_{ywe} = \text{Min}(\phi_{sh, x} * f_{ywe}, \phi_{sh, y} * f_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $\phi_{sh, \min} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\phi_{sh, x} * f_{ywe} = \phi_{sh1} * f_{ywe1} + \phi_{sh2} * f_{ywe2} = 1.38262$$

$$\phi_{sh1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir\_1} * n_{s\_1} = 157.0796$$

$$\text{No stirrups, } n_{s\_1} = 2.00$$

$$h_1 = 450.00$$

$$\phi_{sh2} (\text{internal}) = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir\_2} * n_{s\_2} = 100.531$$

$$\text{No stirrups, } n_{s\_2} = 2.00$$

$$h_2 = 250.00$$

$$\phi_{sh, y} * f_{ywe} = \phi_{sh1} * f_{ywe1} + \phi_{sh2} * f_{ywe2} = 1.38262$$

$$\phi_{sh1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir\_1} * n_{s\_1} = 157.0796$$

$$\text{No stirrups, } n_{s\_1} = 2.00$$

$h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 \cdot ns\_2 = 100.531$   
 $No \text{ stirups, } ns\_2 = 2.00$   
 $h2 = 250.00$

$Asec = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$

$fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$   
 $sh1 = 0.0048696$

$ft1 = 479.7871$   
 $fy1 = 399.8226$

$su1 = 0.0066488$

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

$lo/lou,min = lb/ld = 0.33981258$

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

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

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs,jacket \cdot Asl,ten,jacket + fs,core \cdot Asl,ten,core) / Asl,ten = 399.8226$

with  $Es1 = (Es,jacket \cdot Asl,ten,jacket + Es,core \cdot Asl,ten,core) / Asl,ten = 200000.00$

$y2 = 0.00152175$

$sh2 = 0.0048696$

$ft2 = 479.7871$

$fy2 = 399.8226$

$su2 = 0.0066488$

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

$lo/lou,min = lb/lb,min = 0.33981258$

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

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs,jacket \cdot Asl,com,jacket + fs,core \cdot Asl,com,core) / Asl,com = 399.8226$

with  $Es2 = (Es,jacket \cdot Asl,com,jacket + Es,core \cdot Asl,com,core) / Asl,com = 200000.00$

$yv = 0.00152175$

$shv = 0.0048696$

$ftv = 507.2537$

$fyv = 422.7114$

$suv = 0.0066488$

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

$lo/lou,min = lb/ld = 0.33981258$

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

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, ASCE 41-17.

with  $fsv = (fs,jacket \cdot Asl,mid,jacket + fs,mid \cdot Asl,mid,core) / Asl,mid = 422.7114$

with  $Esu = (Es,jacket \cdot Asl,mid,jacket + Es,mid \cdot Asl,mid,core) / Asl,mid = 200000.00$

$1 = Asl,ten / (b \cdot d) \cdot (fs1 / fc) = 0.0752324$

$2 = Asl,com / (b \cdot d) \cdot (fs2 / fc) = 0.0752324$

$v = Asl,mid / (b \cdot d) \cdot (fsv / fc) = 0.02812438$

and confined core properties:



$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.09371431$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09371431$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$   
 $l_b = 300.00$   
 $l_d = 882.8396$   
 Calculation of  $l_b$ ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 655.558$   
 Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$

Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$   
 $V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$   
 $V_{Col0} = 567563.724$   
 $knl = 1$  (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)  
 Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $Mu = 1.4404090E-011$   
 $Vu = 2.0531359E-031$   
 $d = 0.8 * h = 360.00$   
 $Nu = 7506.808$   
 $Ag = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $Av = 157079.633$

$f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f ((11-3)-(11.4), ACI 440) = 214457.247$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} \cdot V_{Col0}$   
 $V_{Col0} = 567563.724$   
 $k_{nl} = 1$  (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)  
 Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot Area\_jacket + f'_{c\_core} \cdot Area\_core) / Area\_section = 28.98765$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.4404090E-011$   
 $V_u = 2.0531359E-031$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f ((11-3)-(11.4), ACI 440) = 214457.247$   
 $f = 0.95$ , 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  $\theta$  is the angle of the crack direction (see KANEPE).  
This later relation, considered as a function  $V_f(\theta, a_1)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe} ((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
with  $f_u = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $b_w = 450.00$

-----  
-----  
End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At local axis: 3  
-----

Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjrs

#### Constant Properties

-----  
Knowledge Factor,  $\phi = 0.85$   
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
Concrete Elasticity,  $E_c = 21019.039$   
Steel Elasticity,  $E_s = 200000.00$   
#####  
Note: Especially for the calculation of moment strengths,  
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
Jacket  
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
Existing Column  
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$   
#####  
External Height,  $H = 450.00$   
External Width,  $W = 450.00$   
Internal Height,  $H = 250.00$   
Internal Width,  $W = 250.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.10542  
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at  $135^\circ$ )  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $\epsilon_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i = 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = -2.7162834E-031$   
EDGE -B-  
Shear Force,  $V_b = 2.7162834E-031$   
BOTH EDGES  
Axial Force,  $F = -7506.808$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{sl,t} = 0.00$   
-Compression:  $A_{sl,c} = 2676.637$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten} = 1137.257$   
-Compression:  $A_{sl,com} = 1137.257$   
-Middle:  $A_{sl,mid} = 402.1239$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$   
with  
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 2.2193E+008$   
 $\mu_{u1+} = 2.2193E+008$ , 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  
 $\mu_{u1-} = 2.2193E+008$ , 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  
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 2.2193E+008$   
 $\mu_{u2+} = 2.2193E+008$ , 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  
 $\mu_{u2-} = 2.2193E+008$ , 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:  
 $\mu_u = 1.9632832E-005$   
 $\mu_u = 2.2193E+008$

with full section properties:

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.00124204$   
 $N = 7506.808$   
 $f_c = 33.00$   
 $\phi_c$  (5A.5, TBDY) = 0.002  
Final value of  $\phi_{cu}$ :  $\phi_{cu}^* = \text{shear\_factor} * \max(\phi_{cu}, \phi_{cc}) = 0.01393923$   
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY:  $\phi_{cu} = 0.01393923$   
we ((5.4c), TBDY) =  $a_s e * \phi_{sh,min} * f_{ywe}/f_{ce} + \min(\phi_{fx}, \phi_{fy}) = 0.06811101$   
where  $\phi_f = a_f * \phi_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)  
 $\phi_{fx} = 0.06628267$

af = 0.54930041  
b = 450.00  
h = 450.00  
From EC8 A.4.4.3(6), pf =  $2t_f/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35), ff,e = 881.8461

---

fy = 0.06628267  
af = 0.54930041  
b = 450.00  
h = 450.00  
From EC8 A.4.4.3(6), pf =  $2t_f/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35), ff,e = 881.8461

---

R = 40.00  
Effective FRP thickness, tf =  $NL \cdot t \cdot \cos(b1) = 1.016$   
fu,f = 1055.00  
Ef = 64828.00  
u,f = 0.015  
ase ((5.4d), TBDY) =  $(ase1 \cdot A_{ext} + ase2 \cdot A_{int}) / A_{sec} = 0.14546167$   
ase1 = 0.12623274  
bo\_1 = 390.00  
ho\_1 = 390.00  
bi2\_1 = 608400.00  
ase2 =  $\text{Max}(ase1, ase2) = 0.18853448$   
bo\_2 = 242.00  
ho\_2 = 242.00  
bi2\_2 = 234256.00  
psh,min\*Fywe =  $\text{Min}(psh,x \cdot Fywe, psh,y \cdot Fywe) = 1.38262$   
Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

---

psh\_x\*Fywe =  $psh1 \cdot Fywe1 + ps2 \cdot Fywe2 = 1.38262$   
ps1 (external) =  $(Ash1 \cdot h1 / s1) / A_{sec} = 0.00116355$   
Ash1 =  $A_{stir\_1} \cdot ns\_1 = 157.0796$   
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) =  $(Ash2 \cdot h2 / s2) / A_{sec} = 0.00103427$   
Ash2 =  $A_{stir\_2} \cdot ns\_2 = 100.531$   
No stirrups, ns\_2 = 2.00  
h2 = 250.00

---

psh\_y\*Fywe =  $psh1 \cdot Fywe1 + ps2 \cdot Fywe2 = 1.38262$   
ps1 (external) =  $(Ash1 \cdot h1 / s1) / A_{sec} = 0.00116355$   
Ash1 =  $A_{stir\_1} \cdot ns\_1 = 157.0796$   
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) =  $(Ash2 \cdot h2 / s2) / A_{sec} = 0.00103427$   
Ash2 =  $A_{stir\_2} \cdot ns\_2 = 100.531$   
No stirrups, ns\_2 = 2.00  
h2 = 250.00

---

Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00  
From ((5.A5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542  
y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488  
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $lo/lou,min = lb/ld = 0.33981258$   
 $su1 = 0.4*esu1\_nominal ((5.5), TBDY) = 0.032$   
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, ASCE 41-17.  
with  $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 399.8226$   
with  $Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $lo/lou,min = lb/lb,min = 0.33981258$   
 $su2 = 0.4*esu2\_nominal ((5.5), TBDY) = 0.032$   
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, ASCE 41-17.  
with  $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226$   
with  $Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $lo/lou,min = lb/ld = 0.33981258$   
 $suv = 0.4*esuv\_nominal ((5.5), TBDY) = 0.032$   
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, ASCE 41-17.  
with  $fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114$   
with  $Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438$   
and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353$   
Case/Assumption: Unconfined full section - Steel rupture  
'satisfies Eq. (4.3)  
--->  
 $v < vs,y2$  - LHS eq.(4.5) is satisfied  
--->  
 $su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

-----  
Calculation of ratio  $lb/ld$

Lap Length:  $l_b/l_d = 0.33981258$   
 $l_b = 300.00$   
 $l_d = 882.8396$   
 Calculation of  $l_b$ , min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 655.558$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$   
 where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$

Calculation of  $\mu_{u1}$ -

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

$\mu_u = 1.9632832E-005$

$\mu_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$\alpha_1$  (5A.5, TBDY) = 0.002

Final value of  $\mu_u$ :  $\mu_u = \text{shear\_factor} \cdot \text{Max}(\mu_u, \mu_c) = 0.01393923$

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

From (5.4b), TBDY:  $\mu_u = 0.01393923$

we ((5.4c), TBDY) =  $\alpha_1 \cdot \text{sh}_{\min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$

where  $f = \alpha_1 \cdot p_f \cdot f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06628267$

$\alpha_1 = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$f_y = 0.06628267$

$\alpha_1 = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$\alpha_{se}$  ((5.4d), TBDY) =  $(\alpha_{se1} \cdot A_{ext} + \alpha_{se2} \cdot A_{int}) / A_{sec} = 0.14546167$

$\alpha_{se1} = 0.12623274$

$bo\_1 = 390.00$   
 $ho\_1 = 390.00$   
 $bi2\_1 = 608400.00$   
 $ase2 = \text{Max}(ase1, ase2) = 0.18853448$   
 $bo\_2 = 242.00$   
 $ho\_2 = 242.00$   
 $bi2\_2 = 234256.00$   
 $psh, min * Fywe = \text{Min}(psh, x * Fywe, psh, y * Fywe) = 1.38262$   
 Expression ((5.4d), TBDY) for  $psh, min * Fywe$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh\_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 * ns\_1 = 157.0796$   
 No stirrups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 * ns\_2 = 100.531$   
 No stirrups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$psh\_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 * ns\_1 = 157.0796$   
 No stirrups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 * ns\_2 = 100.531$   
 No stirrups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$Asec = 202500.00$

$s1 = 300.00$

$s2 = 120.00$

$fywe1 = 694.45$

$fywe2 = 555.55$

$fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$

$c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$

$sh1 = 0.0048696$

$ft1 = 479.7871$

$fy1 = 399.8226$

$su1 = 0.0066488$

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

$lo/lo, min = lb/ld = 0.33981258$

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

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

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered characteristic value  $fsy1 = fs1 / 1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs\_jacket * Asl, ten, jacket + fs\_core * Asl, ten, core) / Asl, ten = 399.8226$

with  $Es1 = (Es\_jacket * Asl, ten, jacket + Es\_core * Asl, ten, core) / Asl, ten = 200000.00$

$y2 = 0.00152175$

$sh2 = 0.0048696$

$ft2 = 479.7871$

$fy2 = 399.8226$

$su2 = 0.0066488$

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

$lo/lo, min = lb/lb, min = 0.33981258$

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

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered



characteristic value  $f_{sy2} = f_{s2}/1.2$ , 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, ASCE 41-17.  
 with  $f_{s2} = (f_{sjacket} \cdot A_{sl,com,jacket} + f_{s,core} \cdot A_{sl,com,core}) / A_{sl,com} = 399.8226$   
 with  $E_{s2} = (E_{sjacket} \cdot A_{sl,com,jacket} + E_{s,core} \cdot A_{sl,com,core}) / A_{sl,com} = 200000.00$   
 $y_v = 0.00152175$   
 $sh_v = 0.0048696$   
 $ft_v = 507.2537$   
 $fy_v = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{u,min} = lb/ld = 0.33981258$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $f_{sv} = (f_{sjacket} \cdot A_{sl,mid,jacket} + f_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 422.7114$   
 with  $E_{sv} = (E_{sjacket} \cdot A_{sl,mid,jacket} + E_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0752324$   
 $2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0752324$   
 $v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.02812438$   
 and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09371431$   
 $2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09371431$   
 $v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$   
 -----  
 Calculation of ratio  $lb/ld$   
 -----  
 Lap Length:  $lb/ld = 0.33981258$   
 $lb = 300.00$   
 $ld = 882.8396$   
 Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $fy = 655.558$   
 Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} < =$   
 8.3 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$   
 where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$   
 -----  
 -----  
 -----

## Calculation of $\mu_{2+}$

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

$$\mu = 1.9632832E-005$$

$$\mu = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, \alpha) = 0.01393923$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01393923$$

$$\mu_{we} ((5.4c), TBDY) = \alpha * \mu_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.06811101$$

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

$$\mu_{fx} = 0.06628267$$

$$\mu_{af} = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{pf} = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$\mu_{fy} = 0.06628267$$

$$\mu_{af} = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{pf} = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

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

$$\alpha_{se} ((5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$\alpha_{se1} = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i,1} = 608400.00$$

$$\alpha_{se2} = \text{Max}(\alpha_{se1}, \alpha_{se2}) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i,2} = 234256.00$$

$$\mu_{psh, \min} * f_{ywe} = \text{Min}(\mu_{psh, x} * f_{ywe}, \mu_{psh, y} * f_{ywe}) = 1.38262$$

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

$$\mu_{psh, x} * f_{ywe} = \mu_{psh1} * f_{ywe1} + \mu_{ps2} * f_{ywe2} = 1.38262$$

$$\mu_{ps1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$\mu_{ps2} (\text{internal}) = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h_2 = 250.00$$

$$\mu_{psh, y} * f_{ywe} = \mu_{psh1} * f_{ywe1} + \mu_{ps2} * f_{ywe2} = 1.38262$$

$$ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / Asec = 0.00116355$$

$$Ash1 = Astir\_1 \cdot ns\_1 = 157.0796$$

$$\text{No stirups, } ns\_1 = 2.00$$

$$h1 = 450.00$$

$$ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$$

$$Ash2 = Astir\_2 \cdot ns\_2 = 100.531$$

$$\text{No stirups, } ns\_2 = 2.00$$

$$h2 = 250.00$$

$$Asec = 202500.00$$

$$s1 = 300.00$$

$$s2 = 120.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

$$\text{From } ((5A5), \text{TB DY}), \text{TB DY: } cc = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$y1 = 0.00152175$$

$$sh1 = 0.0048696$$

$$ft1 = 479.7871$$

$$fy1 = 399.8226$$

$$su1 = 0.0066488$$

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

$$lo/lou, \min = lb/ld = 0.33981258$$

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

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

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.

$$y1, sh1, ft1, fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 \cdot (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs1 = (fs\_jacket \cdot Asl, \text{ten, jacket} + fs\_core \cdot Asl, \text{ten, core}) / Asl, \text{ten} = 399.8226$$

$$\text{with } Es1 = (Es\_jacket \cdot Asl, \text{ten, jacket} + Es\_core \cdot Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$$

$$y2 = 0.00152175$$

$$sh2 = 0.0048696$$

$$ft2 = 479.7871$$

$$fy2 = 399.8226$$

$$su2 = 0.0066488$$

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

$$lo/lou, \min = lb/lb, \min = 0.33981258$$

$$su2 = 0.4 \cdot esu2\_nominal ((5.5), \text{TB DY}) = 0.032$$

$$\text{From table 5A.1, TB DY: } esu2\_nominal = 0.08,$$

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.

$$y1, sh1, ft1, fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 \cdot (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs2 = (fs\_jacket \cdot Asl, \text{com, jacket} + fs\_core \cdot Asl, \text{com, core}) / Asl, \text{com} = 399.8226$$

$$\text{with } Es2 = (Es\_jacket \cdot Asl, \text{com, jacket} + Es\_core \cdot Asl, \text{com, core}) / Asl, \text{com} = 200000.00$$

$$yv = 0.00152175$$

$$shv = 0.0048696$$

$$ftv = 507.2537$$

$$fyv = 422.7114$$

$$suv = 0.0066488$$

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

$$lo/lou, \min = lb/ld = 0.33981258$$

$$suv = 0.4 \cdot esuv\_nominal ((5.5), \text{TB DY}) = 0.032$$

$$\text{From table 5A.1, TB DY: } esuv\_nominal = 0.08,$$

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.

$$y1, sh1, ft1, fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 \cdot (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fsv = (fs\_jacket \cdot Asl, \text{mid, jacket} + fs\_mid \cdot Asl, \text{mid, core}) / Asl, \text{mid} = 422.7114$$

$$\text{with } Esv = (Es\_jacket \cdot Asl, \text{mid, jacket} + Es\_mid \cdot Asl, \text{mid, core}) / Asl, \text{mid} = 200000.00$$

$$1 = Asl, \text{ten} / (b \cdot d) \cdot (fs1 / fce) = 0.0752324$$

$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.0752324$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.02812438$   
 and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.09371431$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09371431$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.16791801$   
 $Mu = M_{Rc} (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$   
 $l_b = 300.00$   
 $l_d = 882.8396$   
 Calculation of  $l_b, min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 655.558$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}, A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$

Calculation of  $Mu_2$ -

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 1.9632832E-005$   
 $Mu = 2.2193E+008$

with full section properties:

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.00124204$   
 $N = 7506.808$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01393923$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01393923$   
 $w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$   
 where  $f = a_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.06628267  
af = 0.54930041  
b = 450.00  
h = 450.00  
From EC8 A4.4.3(6), pf = 2tf/bw = 0.00451556  
bw = 450.00  
effective stress from (A.35), ff,e = 881.8461

fy = 0.06628267  
af = 0.54930041  
b = 450.00  
h = 450.00  
From EC8 A4.4.3(6), pf = 2tf/bw = 0.00451556  
bw = 450.00  
effective stress from (A.35), ff,e = 881.8461

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) = (ase1\*Aext+ase2\*Aint)/Asec = 0.14546167  
ase1 = 0.12623274  
bo\_1 = 390.00  
ho\_1 = 390.00  
bi2\_1 = 608400.00  
ase2 = Max(ase1,ase2) = 0.18853448  
bo\_2 = 242.00  
ho\_2 = 242.00  
bi2\_2 = 234256.00

psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 1.38262  
Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00  
From ((5.A5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542  
y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.33981258$   
 $su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$   
 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, ASCE 41-17.  
 with  $fs_1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 399.8226$   
 with  $Es_1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$   
 $y_2 = 0.00152175$   
 $sh_2 = 0.0048696$   
 $ft_2 = 479.7871$   
 $fy_2 = 399.8226$   
 $su_2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.33981258$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 399.8226$   
 with  $Es_2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$   
 $y_v = 0.00152175$   
 $sh_v = 0.0048696$   
 $ft_v = 507.2537$   
 $fy_v = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.33981258$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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, ASCE 41-17.  
 with  $fsv = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 422.7114$   
 with  $Es_v = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.0752324$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.0752324$   
 $v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.02812438$   
 and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.09371431$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.09371431$   
 $v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

#### Calculation of ratio $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot Area\_jacket + f'_{c\_core} \cdot Area\_core) / Area\_section = 28.98765$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \min(A_{tr\_x}, A_{tr\_y}) = 257.6106$

where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \max(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

Calculation of Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 567563.724$

Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$V_{Col0} = 567563.724$

$k_{nl} = 1$  (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)

Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot Area\_jacket + f'_{c\_core} \cdot Area\_core) / Area\_section = 28.98765$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.0463738E-012$

$V_u = 2.7162834E-031$

$d = 0.8 \cdot h = 360.00$

$N_u = 7506.808$

$A_g = 202500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 300.00$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$s/d = 0.83333333$

$V_{s2} = 74466.637$  is calculated for core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 120.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.60$

$V_f ((11-3)-(11.4), ACI 440) = 214457.247$

$f = 0.95$ , 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:  $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL \cdot t / \text{NoDir} = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 407.00  
 $ffe$  ((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:  $V_s + V_f \leq 579413.096$   
 $bw = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$   
 $V_{r2} = V_{Col}((10.3), \text{ASCE } 41-17) = knl \cdot V_{Col0}$   
 $V_{Col0} = 567563.724$   
 $knl = 1$  (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)  
 Mean concrete strength:  $fc' = (fc'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + fc'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.0463738E-012$   
 $\mu_v = 2.7162834E-031$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 214457.247  
 $f = 0.95$ , 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,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL \cdot t / \text{NoDir} = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 407.00  
 $ffe$  ((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:  $V_s + V_f \leq 579413.096$   
 $bw = 450.00$

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
 At local axis: 2



Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcjrs

#### Constant Properties

Knowledge Factor,  $\gamma = 0.85$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -3.5391295E-010$

Shear Force,  $V_2 = -7697.601$

Shear Force,  $V_3 = 1.7235006E-013$

Axial Force,  $F = -7503.728$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 1137.257$

-Compression:  $As_c = 1539.38$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

-Middle:  $As_{mid} = 402.1239$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

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

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

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

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten,core} = 307.8761$

-Compression:  $A_{sl,com,core} = 307.8761$

-Middle:  $A_{sl,mid,core} = 0.00$

Mean Diameter of Tension Reinforcement,  $DbL = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = u = 0.0027627$

$u = y + p = 0.00325024$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00325024$  ((4.29), Biskinis Phd))

$M_y = 1.7613E+008$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.7095E+013$

factor = 0.30

$A_g = 202500.00$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$

$N = 7503.728$

$E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 9.0315E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

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

$y_{ten} = 6.1806747E-006$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / l_d)^{2/3}) = 374.3546$

$d = 407.00$

$y = 0.25591435$

$A = 0.0147239$

$B = 0.00818869$

with  $p_t = 0.00430549$

$p_c = 0.00620943$

$p_v = 0.0021956$

$N = 7503.728$

$b = 450.00$

" = 0.10565111

$y_{comp} = 2.2127278E-005$

with  $f_c' (12.3, (ACI 440)) = 34.40847$

$f_c = 33.00$

$f_l = 0.82797802$

$b = 450.00$

$h = 450.00$

$A_g = 202500.00$

From (12.9), ACI 440:  $k_a = 0.54261599$

$g = p_t + p_c + p_v = 0.01461445$

$r_c = 40.00$

$A_e / A_c = 0.54261599$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.25471862$

$A = 0.01452515$

$B = 0.00807924$

with  $E_s = 200000.00$

Calculation of ratio  $l_b / l_d$

Lap Length:  $l_d/l_{d,min} = 0.42476573$

$l_b = 300.00$

$l_d = 706.2717$

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

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 257.6106$

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

$s = \max(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

-----  
- Calculation of  $p$  -  
-----

From table 10-8:  $p = 0.00$

with:

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

shear control ratio  $V_y E / V_{col} E = 0.26068017$

$d = d_{external} = 407.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00430549$

jacket:  $s_1 = A_{v1} \cdot h_1 / (s_1 \cdot A_g) = 0.00116355$

$A_{v1} = 157.0796$ , is the total area of all stirrups parallel to loading (shear) direction

$h_1 = 450.00$

$s_1 = 300.00$

core:  $s_2 = A_{v2} \cdot h_2 / (s_2 \cdot A_g) = 0.00103427$

$A_{v2} = 100.531$ , is the total area of all stirrups parallel to loading (shear) direction

$h_2 = 250.00$

$s_2 = 120.00$

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.

For the normalisation  $f_s$  of jacket is used.

$N_{UD} = 7503.728$

$A_g = 202500.00$

$f_{cE} = (f_{c,jacket} \cdot Area_{jacket} + f_{c,core} \cdot Area_{core}) / section\_area = 28.98765$

$f_{yIE} = (f_{y,ext\_Long\_Reinf} \cdot Area_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} \cdot Area_{int\_Long\_Reinf}) / Area_{Tot\_Long\_Rein} = 529.9972$

$f_{yIE} = (f_{y,ext\_Trans\_Reinf} \cdot s_1 + f_{y,int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 503.2682$

$p_l = Area_{Tot\_Long\_Rein} / (b \cdot d) = 0.01461445$

$b = 450.00$

$d = 407.00$

$f_{cE} = 28.98765$

-----  
End Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (a)

## Calculation No. 3

column C1, Floor 1

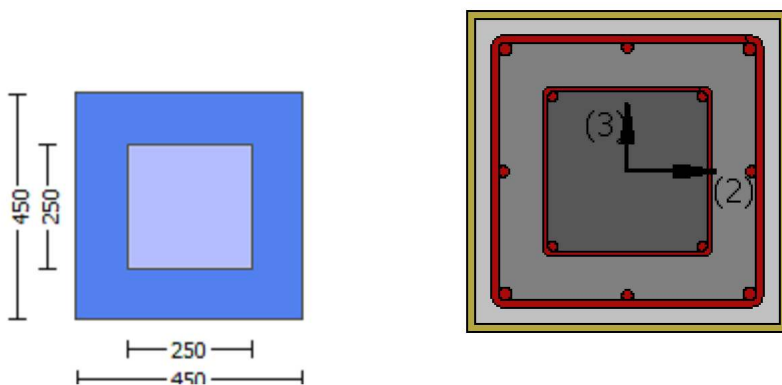
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

New material: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material: Steel Strength,  $f_s = f_{sm} = 555.56$

Existing Column

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

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

#####

External Height, H = 450.00  
 External Width, W = 450.00  
 Internal Height, H = 250.00  
 Internal Width, W = 250.00  
 Cover Thickness, c = 25.00  
 Element Length, L = 3000.00  
 Primary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_o = l_b = 300.00$   
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $ε_{fu} = 0.01$   
 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

EDGE -A-  
 Bending Moment,  $M_a = -3.5391295E-010$   
 Shear Force,  $V_a = 1.7235006E-013$   
 EDGE -B-  
 Bending Moment,  $M_b = -1.6313530E-010$   
 Shear Force,  $V_b = -1.7235006E-013$   
 BOTH EDGES  
 Axial Force,  $F = -7503.728$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $As_t = 1137.257$   
   -Compression:  $As_c = 1539.38$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $As_{t,ten} = 1137.257$   
   -Compression:  $As_{c,com} = 1137.257$   
   -Middle:  $As_{mid} = 402.1239$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41-17: Final Shear Capacity  $V_R = V_n = 447100.515$   
 $V_n ((10.3), ASCE 41-17) = knl * V_{Col0} = 526000.605$   
 $V_{Col} = 526000.605$   
 $knl = 1.00$   
 $displacement\_ductility\_demand = 0.00$

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

= 1 (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_{c\_jacket} * Area\_jacket + f'_{c\_core} * Area\_core) / Area\_section = 22.22222$ , but  $f_c^{0.5} < = 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $M_u = 3.5391295E-010$   
 $V_u = 1.7235006E-013$   
 $d = 0.8 * h = 360.00$   
 $N_u = 7503.728$   
 $Ag = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 129852.496$   
 where:

Vs1 = 62831.853 is calculated for jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 500.00$$

$$s = 300.00$$

Vs1 is multiplied by Col1 = 0.66666667

$$s/d = 0.83333333$$

Vs2 = 67020.643 is calculated for core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 400.00$$

$$s = 120.00$$

Vs2 is multiplied by Col2 = 1.00

$$s/d = 0.60$$

Vf ((11-3)-(11.4), ACI 440) = 214457.247

f = 0.95, for fully-wrapped sections

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

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

This later relation, considered as a function  $Vf(, )$ , 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:  $a_1 = b_1 + 90^\circ = 90.00$

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

total thickness per orientation,  $tf_1 = NL \cdot t / \text{NoDir} = 1.016$

$df_v = d$  (figure 11.2, ACI 440) = 407.00

$ffe$  ((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:  $V_s + V_f \leq 507312.442$

$$bw = 450.00$$

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  $\theta = 5.1751012E-023$

$$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00325024 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 1.7613E+008$$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 2.7095E+013$

$$\text{factor} = 0.30$$

$$A_g = 202500.00$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$$

$$N = 7503.728$$

$$E_c \cdot I_g = E_{c_{\text{jacket}}} \cdot I_{g_{\text{jacket}}} + E_{c_{\text{core}}} \cdot I_{g_{\text{core}}} = 9.0315E+013$$

Calculation of Yielding Moment  $M_y$

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

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

$$y_{\text{ten}} = 6.1806747E-006$$

$$\text{with ((10.1), ASCE 41-17)} f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 374.3546$$

$$d = 407.00$$

$$y = 0.25591435$$

$$A = 0.0147239$$

$$B = 0.00818869$$

$$\text{with } pt = 0.00620943$$

$$pc = 0.00620943$$

$$pv = 0.0021956$$

$$N = 7503.728$$

$b = 450.00$   
 $\rho = 0.10565111$   
 $y_{comp} = 2.2127278E-005$   
 with  $f_c^* (12.3, (ACI\ 440)) = 34.40847$   
 $f_c = 33.00$   
 $f_l = 0.82797802$   
 $b = 450.00$   
 $h = 450.00$   
 $A_g = 202500.00$   
 From (12.9), ACI 440:  $k_a = 0.54261599$   
 $g = p_t + p_c + p_v = 0.01461445$   
 $r_c = 40.00$   
 $A_e/A_c = 0.54261599$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.25471862$   
 $A = 0.01452515$   
 $B = 0.00807924$   
 with  $E_s = 200000.00$

Calculation of ratio  $I_b/I_d$

Lap Length:  $I_d/I_{d,min} = 0.42476573$

$I_b = 300.00$

$I_d = 706.2717$

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

$= 1$

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$

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

$s = \max(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

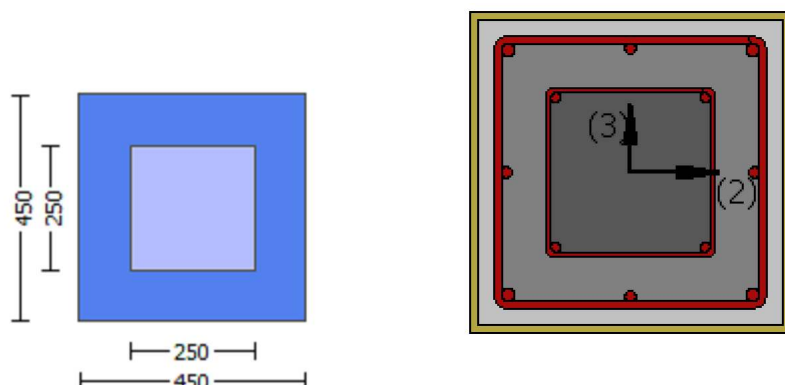
End Of Calculation of Shear Capacity for element: column JC1 of floor 1

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 JC1 of floor 1  
 At Shear local axis: 3  
 (Bending local axis: 2)  
 Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

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

#####

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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



Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 2.0531359E-031$

EDGE -B-

Shear Force,  $V_b = -2.0531359E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

-Middle:  $As_{mid} = 402.1239$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$  with

$M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 2.2193E+008$

$\mu_{u1+} = 2.2193E+008$ , 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

$\mu_{u1-} = 2.2193E+008$ , 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

$M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 2.2193E+008$

$\mu_{u2+} = 2.2193E+008$ , 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

$\mu_{u2-} = 2.2193E+008$ , 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:

$\phi_u = 1.9632832E-005$

$\mu_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

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

Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$

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

From (5.4b), TBDY:  $c_u = 0.01393923$

$w_e$  ((5.4c), TBDY) =  $a_{se} * \text{sh\_min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$

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

$f_x = 0.06628267$

$a_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$f_y = 0.06628267$

$a_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$R = 40.00$

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) =  $(a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$

$a_{se1} = 0.12623274$

$bo\_1 = 390.00$

$ho\_1 = 390.00$

$bi2\_1 = 608400.00$

$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$

$bo\_2 = 242.00$

$ho\_2 = 242.00$

$bi2\_2 = 234256.00$

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 1.38262$

Expression ((5.4d), TBDY) for  $p_{sh,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 1.38262$

$ps1$  (external) =  $(A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$

$A_{sh1} = A_{stir\_1} * ns\_1 = 157.0796$

No stirrups,  $ns\_1 = 2.00$

$h_1 = 450.00$

$ps2$  (internal) =  $(A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$

$A_{sh2} = A_{stir\_2} * ns\_2 = 100.531$

No stirrups,  $ns\_2 = 2.00$

$h_2 = 250.00$

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 1.38262$

$ps1$  (external) =  $(A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$

$A_{sh1} = A_{stir\_1} * ns\_1 = 157.0796$

No stirrups,  $ns\_1 = 2.00$

$h_1 = 450.00$

$ps2$  (internal) =  $(A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$

$A_{sh2} = A_{stir\_2} * ns\_2 = 100.531$

No stirrups,  $ns\_2 = 2.00$

$h_2 = 250.00$

$A_{sec} = 202500.00$

$s_1 = 300.00$

$s_2 = 120.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$

```

c = confinement factor = 1.10542
y1 = 0.00152175
sh1 = 0.0048696
ft1 = 479.7871
fy1 = 399.8226
su1 = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258
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, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 399.8226
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00152175
sh2 = 0.0048696
ft2 = 479.7871
fy2 = 399.8226
su2 = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.33981258
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, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00152175
shv = 0.0048696
ftv = 507.2537
fyv = 422.7114
suv = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258
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, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
c = confinement factor = 1.10542
1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied

```

```

--->
su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008
u = su (4.1) = 1.9632832E-005
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.33981258
lb = 300.00
ld = 882.8396
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.98765, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.86234
Atr = Min(Atrx,Atry) = 257.6106
where Atrx, Atry are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(sexternal,sinternal) = 300.00
n = 12.00
-----
-----
-----

Calculation of Mu1-
-----
-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.9632832E-005
Mu = 2.2193E+008
-----

with full section properties:
b = 450.00
d = 407.00
d' = 43.00
v = 0.00124204
N = 7506.808
fc = 33.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01393923
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01393923
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.06811101
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
-----
fx = 0.06628267
af = 0.54930041
b = 450.00
h = 450.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556
bw = 450.00
effective stress from (A.35), ff,e = 881.8461
-----
fy = 0.06628267
af = 0.54930041
b = 450.00
h = 450.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556
bw = 450.00
effective stress from (A.35), ff,e = 881.8461
-----

```

$R = 40.00$   
 Effective FRP thickness,  $t_f = N L * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.14546167$   
 $ase_1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi_2 = 608400.00$   
 $ase_2 = \max(ase_1, ase_2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi_2 = 234256.00$   
 $psh_{,min} * F_{ywe} = \min(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 1.38262$   
 Expression ((5.4d), TBDY) for  $psh_{,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 1.38262$   
 $ps_1 \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir\_1} * ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2 \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir\_2} * ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

$psh_{,y} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 1.38262$   
 $ps_1 \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir\_1} * ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2 \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir\_2} * ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

$A_{sec} = 202500.00$   
 $s_1 = 300.00$   
 $s_2 = 120.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y_1 = 0.00152175$   
 $sh_1 = 0.0048696$   
 $ft_1 = 479.7871$   
 $fy_1 = 399.8226$   
 $su_1 = 0.0066488$

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

$lo/lo_{u,min} = l_b / l_d = 0.33981258$   
 $su_1 = 0.4 * esu_{1,nominal}((5.5), TBDY) = 0.032$

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, ASCE 41-17.

with  $fs_1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 399.8226$

with  $Es_1 = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.00152175$   
 $sh_2 = 0.0048696$   
 $ft_2 = 479.7871$   
 $fy_2 = 399.8226$   
 $su_2 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.33981258$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
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, ASCE 41-17.  
with  $fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 399.8226$   
with  $Es_2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$   
 $y_v = 0.00152175$   
 $sh_v = 0.0048696$   
 $ft_v = 507.2537$   
 $fy_v = 422.7114$   
 $suv = 0.0066488$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.33981258$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
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, ASCE 41-17.  
with  $fsv = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 422.7114$   
with  $Es_v = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.0752324$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.0752324$   
 $v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.02812438$   
and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.09371431$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.09371431$   
 $v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.03503353$   
Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)  
--->  
 $v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied  
--->  
 $su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

#### Calculation of ratio $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$   
 $l_b = 300.00$   
 $l_d = 882.8396$   
Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
Mean strength value of all re-bars:  $fy = 655.558$   
Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} < =$   
8.3 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$

$$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$$

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$$

$$n = 12.00$$

Calculation of  $\mu_{2+}$

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

$$\mu = 1.9632832E-005$$

$$\mu_{2+} = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_{cu} = \text{shear\_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.01393923$$

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

$$\text{From (5.4b), TBDY: } \mu_{cu} = 0.01393923$$

$$\mu_{we} \text{ ((5.4c), TBDY)} = \alpha_{se} * \mu_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.06811101$$

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

$$\mu_{fx} = 0.06628267$$

$$\alpha_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{pf} = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$\mu_{fy} = 0.06628267$$

$$\alpha_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{pf} = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(\theta_1) = 1.016$$

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

$$E_f = 64828.00$$

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

$$\alpha_{se} \text{ ((5.4d), TBDY)} = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$\alpha_{se1} = 0.12623274$$

$$b_{o\_1} = 390.00$$

$$h_{o\_1} = 390.00$$

$$b_{i2\_1} = 608400.00$$

$$\alpha_{se2} = \text{Max}(\alpha_{se1}, \alpha_{se2}) = 0.18853448$$

$$b_{o\_2} = 242.00$$

$$h_{o\_2} = 242.00$$

$$b_{i2\_2} = 234256.00$$

$$\mu_{psh, \min} * f_{ywe} = \text{Min}(\mu_{psh, x} * f_{ywe}, \mu_{psh, y} * f_{ywe}) = 1.38262$$

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

$$\mu_{psh, x} * f_{ywe} = \mu_{psh1} * f_{ywe1} + \mu_{ps2} * f_{ywe2} = 1.38262$$

$$\mu_{ps1} \text{ (external)} = (\alpha_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$\alpha_{sh1} = A_{stir\_1} * n_{s\_1} = 157.0796$$

$$\text{No stirrups, } n_{s\_1} = 2.00$$

$h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 \cdot ns\_2 = 100.531$   
 No stirups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$psh\_y \cdot Fywe = psh1 \cdot Fywe1 + ps2 \cdot Fywe2 = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 \cdot ns\_1 = 157.0796$   
 No stirups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 \cdot ns\_2 = 100.531$   
 No stirups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$Asec = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$

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

$lo/lou, min = lb/ld = 0.33981258$

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

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

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs\_jacket \cdot Asl, ten, jacket + fs\_core \cdot Asl, ten, core) / Asl, ten = 399.8226$

with  $Es1 = (Es\_jacket \cdot Asl, ten, jacket + Es\_core \cdot Asl, ten, core) / Asl, ten = 200000.00$

$y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$

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

$lo/lou, min = lb/lb, min = 0.33981258$

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

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y2, sh2, ft2, fy2$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs\_jacket \cdot Asl, com, jacket + fs\_core \cdot Asl, com, core) / Asl, com = 399.8226$

with  $Es2 = (Es\_jacket \cdot Asl, com, jacket + Es\_core \cdot Asl, com, core) / Asl, com = 200000.00$

$yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$

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

$lo/lou, min = lb/ld = 0.33981258$

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

From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,



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

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 422.7114$

with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 200000.00$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0752324$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0752324$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$f_{cc}$  (5A.2, TBDY) = 36.47874

$cc$  (5A.5, TBDY) = 0.00305417

$c$  = confinement factor = 1.10542

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.09371431$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09371431$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.03503353$

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) = 0.16791801

$\mu_u = M_{Rc}$  (4.14) = 2.2193E+008

$u = \mu_u$  (4.1) = 1.9632832E-005

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot A_{jacket} + f'_{c,core} \cdot A_{core})/A_{section} = 28.98765$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

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

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

Calculation of  $\mu_{u2}$

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

$u = 1.9632832E-005$

$\mu_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

co (5A.5, TBDY) = 0.002

Final value of cu:  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01393923$

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

From (5.4b), TBDY:  $cu = 0.01393923$

we ((5.4c), TBDY) =  $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.06811101$

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

-----  
 $fx = 0.06628267$

$af = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $ff_e = 881.8461$

-----  
 $fy = 0.06628267$

$af = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $ff_e = 881.8461$

-----  
 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.14546167$

$ase1 = 0.12623274$

$bo_1 = 390.00$

$ho_1 = 390.00$

$bi2_1 = 608400.00$

$ase2 = \text{Max}(ase1, ase2) = 0.18853448$

$bo_2 = 242.00$

$ho_2 = 242.00$

$bi2_2 = 234256.00$

$psh_{min} * fy_{we} = \text{Min}(psh_x * fy_{we}, psh_y * fy_{we}) = 1.38262$

Expression ((5.4d), TBDY) for  $psh_{min} * fy_{we}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $psh_x * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 1.38262$

$ps1$  (external) =  $(Ash1 * h1 / s1) / A_{sec} = 0.00116355$

$Ash1 = Astir_1 * ns_1 = 157.0796$

No stirrups,  $ns_1 = 2.00$

$h1 = 450.00$

$ps2$  (internal) =  $(Ash2 * h2 / s2) / A_{sec} = 0.00103427$

$Ash2 = Astir_2 * ns_2 = 100.531$

No stirrups,  $ns_2 = 2.00$

$h2 = 250.00$

-----  
 $psh_y * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 1.38262$

$ps1$  (external) =  $(Ash1 * h1 / s1) / A_{sec} = 0.00116355$

$Ash1 = Astir_1 * ns_1 = 157.0796$

No stirrups,  $ns_1 = 2.00$

$h1 = 450.00$

$ps2$  (internal) =  $(Ash2 * h2 / s2) / A_{sec} = 0.00103427$

$Ash2 = Astir_2 * ns_2 = 100.531$

No stirrups,  $ns_2 = 2.00$

$h2 = 250.00$

-----  
 $A_{sec} = 202500.00$

$s1 = 300.00$

$s2 = 120.00$

$fy_{we1} = 694.45$

$fy_{we2} = 555.55$

$f_{ce} = 33.00$

From ((5.A.5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/ld = 0.33981258$   
 $su1 = 0.4*esu1\_nominal ((5.5), TBDY) = 0.032$   
 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, ASCE 41-17.  
 with  $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 399.8226$   
 with  $Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/lb,min = 0.33981258$   
 $su2 = 0.4*esu2\_nominal ((5.5), TBDY) = 0.032$   
 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, ASCE 41-17.  
 with  $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226$   
 with  $Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/ld = 0.33981258$   
 $suv = 0.4*esuv\_nominal ((5.5), TBDY) = 0.032$   
 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, ASCE 41-17.  
 with  $fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114$   
 with  $Es_v = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438$   
 and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->

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

---->

$$su(4.9) = 0.16791801$$

$$Mu = MRc(4.14) = 2.2193E+008$$

$$u = su(4.1) = 1.9632832E-005$$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Lap Length:  $l_b/l_d = 0.33981258$

$$l_b = 300.00$$

$$l_d = 882.8396$$

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

$$db = 16.66667$$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

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

$$s = \text{Max}(s_{external}, s_{internal}) = 300.00$$

$$n = 12.00$$

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$$V_{Col0} = 567563.724$$

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

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

-----  
= 1 (normal-weight concrete)

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$Mu = 1.4404090E-011$$

$$Vu = 2.0531359E-031$$

$$d = 0.8 \cdot h = 360.00$$

$$Nu = 7506.808$$

$$Ag = 202500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 144280.365$$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 300.00$$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$$s/d = 0.83333333$$

$V_{s2} = 74466.637$  is calculated for core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 444.44$$

$$s = 120.00$$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$$s/d = 0.60$$

$$V_f((11-3)-(11.4), ACI 440) = 214457.247$$

$f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL \cdot t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$   
 $V_{r2} = V_{Col}((10.3), \text{ASCE 41-17}) = knl \cdot V_{ColO}$   
 $V_{ColO} = 567563.724$   
 $knl = 1$  (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).

$\gamma = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot \text{Area}_{jacket} + f'_{c\_core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 28.98765$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.4404090E-011$   
 $\nu_u = 2.0531359E-031$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f((11-3)-(11.4), \text{ACI 440}) = 214457.247$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL \cdot t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$

bw = 450.00

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjrs

#### Constant Properties

Knowledge Factor,  $\phi = 0.85$   
Mean strength values are used for both shear and moment calculations.  
Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,  
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

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

#####

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $ef_u = 0.01$

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,  $V_a = -2.7162834E-031$

EDGE -B-

Shear Force,  $V_b = 2.7162834E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{ten} = 1137.257$

-Compression:  $As_{com} = 1137.257$

-Middle:  $As_{mid} = 402.1239$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.2193E+008$

$Mu_{1+} = 2.2193E+008$ , 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

$Mu_{1-} = 2.2193E+008$ , 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.2193E+008$

$Mu_{2+} = 2.2193E+008$ , 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

$Mu_{2-} = 2.2193E+008$ , 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:

$\phi_u = 1.9632832E-005$

$M_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

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

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_{co}) = 0.01393923$

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

From (5.4b), TBDY:  $\phi_u = 0.01393923$

$\phi_{we} ((5.4c), TBDY) = \phi_u^* \cdot \phi_{sh,min} \cdot f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.06811101$

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

$\phi_{fx} = 0.06628267$

$\phi_{fy} = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $\phi_{sh,min} = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$\phi_{fx} = 0.06628267$

$\phi_{fy} = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $\phi_{sh,min} = 2t_f/bw = 0.00451556$

bw = 450.00  
effective stress from (A.35),  $f_{f,e} = 881.8461$

R = 40.00  
Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $ase((5.4d), TBDY) = (ase_1 \cdot A_{ext} + ase_2 \cdot A_{int}) / A_{sec} = 0.14546167$   
 $ase_1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi2_1 = 608400.00$   
 $ase_2 = \max(ase_1, ase_2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi2_2 = 234256.00$

$psh_{,min} \cdot F_{ywe} = \min(psh_{,x} \cdot F_{ywe}, psh_{,y} \cdot F_{ywe}) = 1.38262$

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

$psh_{,x} \cdot F_{ywe} = psh_1 \cdot F_{ywe1} + ps_2 \cdot F_{ywe2} = 1.38262$   
 $ps_1 \text{ (external)} = (Ash_1 \cdot h_1 / s_1) / A_{sec} = 0.00116355$   
 $Ash_1 = Astir_1 \cdot ns_1 = 157.0796$   
No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2 \text{ (internal)} = (Ash_2 \cdot h_2 / s_2) / A_{sec} = 0.00103427$   
 $Ash_2 = Astir_2 \cdot ns_2 = 100.531$   
No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

$psh_{,y} \cdot F_{ywe} = psh_1 \cdot F_{ywe1} + ps_2 \cdot F_{ywe2} = 1.38262$   
 $ps_1 \text{ (external)} = (Ash_1 \cdot h_1 / s_1) / A_{sec} = 0.00116355$   
 $Ash_1 = Astir_1 \cdot ns_1 = 157.0796$   
No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2 \text{ (internal)} = (Ash_2 \cdot h_2 / s_2) / A_{sec} = 0.00103427$   
 $Ash_2 = Astir_2 \cdot ns_2 = 100.531$   
No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

$A_{sec} = 202500.00$   
 $s_1 = 300.00$   
 $s_2 = 120.00$   
 $fy_{we1} = 694.45$   
 $fy_{we2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$

$c = \text{confinement factor} = 1.10542$

$y_1 = 0.00152175$   
 $sh_1 = 0.0048696$   
 $ft_1 = 479.7871$   
 $fy_1 = 399.8226$   
 $su_1 = 0.0066488$

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

$lo/lo_{u,min} = lb/ld = 0.33981258$

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

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  $fs_1 = fs_1 / 1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_1 = (fs_{jacket} \cdot A_{sl,ten,jacket} + fs_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 399.8226$

with  $Es_1 = (Es_{jacket} \cdot A_{sl,ten,jacket} + Es_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.00152175$   
 $sh_2 = 0.0048696$



```

ft2 = 479.7871
fy2 = 399.8226
su2 = 0.0066488
    using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.33981258
    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, ASCE 41-17.
    with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226
    with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
    yv = 0.00152175
    shv = 0.0048696
    ftv = 507.2537
    fyv = 422.7114
    suv = 0.0066488
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 0.33981258
    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, ASCE 41-17.
    with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
    2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
    v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438
    and confined core properties:
    b = 390.00
    d = 377.00
    d' = 13.00
    fcc (5A.2, TBDY) = 36.47874
    cc (5A.5, TBDY) = 0.00305417
    c = confinement factor = 1.10542
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
    2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
    v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353
    Case/Assumption: Unconfined full section - Steel rupture
    ' satisfies Eq. (4.3)
    --->
    v < vs,y2 - LHS eq.(4.5) is satisfied
    --->
    su (4.9) = 0.16791801
    Mu = MRc (4.14) = 2.2193E+008
    u = su (4.1) = 1.9632832E-005

```

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

```

--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008
u = su (4.1) = 1.9632832E-005

```

#### Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.33981258
lb = 300.00
lb = 882.8396
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.98765, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80

```

$e = 1.00$   
 $cb = 25.00$   
 $Ktr = 2.86234$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$   
 $n = 12.00$

Calculation of  $\mu_1$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:  
 $\mu = 1.9632832E-005$   
 $\mu = 2.2193E+008$

with full section properties:

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.00124204$   
 $N = 7506.808$   
 $f_c = 33.00$   
 $\alpha (5A.5, \text{TBDY}) = 0.002$   
 Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu, \alpha) = 0.01393923$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\mu = 0.01393923$   
 $\mu (5.4c, \text{TBDY}) = \alpha * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$   
 where  $f = \alpha * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06628267$   
 $\alpha_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$   
 $b_w = 450.00$   
 effective stress from (A.35),  $f_{fe} = 881.8461$

$f_y = 0.06628267$   
 $\alpha_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$   
 $b_w = 450.00$   
 effective stress from (A.35),  $f_{fe} = 881.8461$

$R = 40.00$   
 Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{f,f} = 0.015$   
 $\alpha_{se} ((5.4d), \text{TBDY}) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.14546167$   
 $\alpha_{se1} = 0.12623274$   
 $b_{o\_1} = 390.00$   
 $h_{o\_1} = 390.00$   
 $b_{i2\_1} = 608400.00$   
 $\alpha_{se2} = \text{Max}(\alpha_{se1}, \alpha_{se2}) = 0.18853448$   
 $b_{o\_2} = 242.00$   
 $h_{o\_2} = 242.00$   
 $b_{i2\_2} = 234256.00$

$p_{sh, \text{min}} * F_{ywe} = \text{Min}(p_{sh, x} * F_{ywe}, p_{sh, y} * F_{ywe}) = 1.38262$   
 Expression ((5.4d), TBDY) for  $p_{sh, \text{min}} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh, x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 1.38262$

$ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 \cdot ns\_1 = 157.0796$   
 $No \text{ stirups, } ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 \cdot ns\_2 = 100.531$   
 $No \text{ stirups, } ns\_2 = 2.00$   
 $h2 = 250.00$

$psh\_y \cdot Fywe = psh1 \cdot Fywe1 + ps2 \cdot Fywe2 = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 \cdot ns\_1 = 157.0796$   
 $No \text{ stirups, } ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 \cdot ns\_2 = 100.531$   
 $No \text{ stirups, } ns\_2 = 2.00$   
 $h2 = 250.00$

$Asec = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $fce = 33.00$

$From ((5A5), TBDY), TBDY: cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$

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

$lo/lou,min = lb/l_d = 0.33981258$   
 $su1 = 0.4 \cdot esu1\_nominal ((5.5), TBDY) = 0.032$

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

$For \text{ calculation of } esu1\_nominal \text{ and } y1, sh1, ft1, fy1, \text{ it is considered}$   
 $characteristic \text{ value } fsy1 = fs1 / 1.2, \text{ from table } 5.1, TBDY.$

$y1, sh1, ft1, fy1, \text{ are also multiplied by } Min(1, 1.25 \cdot (lb/l_d)^{2/3}), \text{ from } 10.3.5, ASCE 41-17.$

$\text{with } fs1 = (fs,jacket \cdot Asl,ten,jacket + fs,core \cdot Asl,ten,core) / Asl,ten = 399.8226$

$\text{with } Es1 = (Es,jacket \cdot Asl,ten,jacket + Es,core \cdot Asl,ten,core) / Asl,ten = 200000.00$

$y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$

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

$lo/lou,min = lb/l_b,min = 0.33981258$   
 $su2 = 0.4 \cdot esu2\_nominal ((5.5), TBDY) = 0.032$

$From \text{ table } 5A.1, TBDY: esu2\_nominal = 0.08,$

$For \text{ calculation of } esu2\_nominal \text{ and } y2, sh2, ft2, fy2, \text{ it is considered}$   
 $characteristic \text{ value } fsy2 = fs2 / 1.2, \text{ from table } 5.1, TBDY.$

$y1, sh1, ft1, fy1, \text{ are also multiplied by } Min(1, 1.25 \cdot (lb/l_d)^{2/3}), \text{ from } 10.3.5, ASCE 41-17.$

$\text{with } fs2 = (fs,jacket \cdot Asl,com,jacket + fs,core \cdot Asl,com,core) / Asl,com = 399.8226$

$\text{with } Es2 = (Es,jacket \cdot Asl,com,jacket + Es,core \cdot Asl,com,core) / Asl,com = 200000.00$

$yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$

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

$l_o/l_{ou,min} = l_b/l_d = 0.33981258$   
 $s_{uv} = 0.4 * e_{suv\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $e_{suv\_nominal} = 0.08$ ,  
 considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $e_{suv\_nominal}$  and  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $f_{yv}$ , it is considered  
 characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1$ ,  $ft_1$ ,  $f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $f_{sv} = (f_{sj\_jacket} * A_{sl,mid,jacket} + f_{s,mid} * A_{sl,mid,core}) / A_{sl,mid} = 422.7114$   
 with  $E_{sv} = (E_{sj\_jacket} * A_{sl,mid,jacket} + E_{s,mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b * d) * (f_{s1} / f_c) = 0.0752324$   
 $2 = A_{sl,com} / (b * d) * (f_{s2} / f_c) = 0.0752324$   
 $v = A_{sl,mid} / (b * d) * (f_{sv} / f_c) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{sl,ten} / (b * d) * (f_{s1} / f_c) = 0.09371431$   
 $2 = A_{sl,com} / (b * d) * (f_{s2} / f_c) = 0.09371431$   
 $v = A_{sl,mid} / (b * d) * (f_{sv} / f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c\_jacket} * Area\_jacket + f'_{c\_core} * Area\_core) / Area\_section = 28.98765$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$

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

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

Calculation of  $Mu_{2+}$

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

$u = 1.9632832E-005$

$Mu = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01393923$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

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

$$f_x = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$a_{se1} = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i2,1} = 608400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i2,2} = 234256.00$$

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $p_{sh,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 1.38262$$

$$p_{s1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$p_{s2} (\text{internal}) = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h_2 = 250.00$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 1.38262$$

$$p_{s1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$p_{s2} (\text{internal}) = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h_2 = 250.00$$

$$A_{sec} = 202500.00$$

$$s_1 = 300.00$$

$$s_2 = 120.00$$

$fy_{we1} = 694.45$   
 $fy_{we2} = 555.55$   
 $f_{ce} = 33.00$   
 From ((5.A.5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $y_1 = 0.00152175$   
 $sh_1 = 0.0048696$   
 $ft_1 = 479.7871$   
 $fy_1 = 399.8226$   
 $su_1 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou, min = lb/ld = 0.33981258$   
 $su_1 = 0.4 * esu_1, nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_1, nominal = 0.08$ ,  
 For calculation of  $esu_1, nominal$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
 characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_1 = (fs_{jacket} * Asl, ten, jacket + fs_{core} * Asl, ten, core) / Asl, ten = 399.8226$   
 with  $Es_1 = (Es_{jacket} * Asl, ten, jacket + Es_{core} * Asl, ten, core) / Asl, ten = 200000.00$   
 $y_2 = 0.00152175$   
 $sh_2 = 0.0048696$   
 $ft_2 = 479.7871$   
 $fy_2 = 399.8226$   
 $su_2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou, min = lb/lb, min = 0.33981258$   
 $su_2 = 0.4 * esu_2, nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_2, nominal = 0.08$ ,  
 For calculation of  $esu_2, nominal$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * Asl, com, jacket + fs_{core} * Asl, com, core) / Asl, com = 399.8226$   
 with  $Es_2 = (Es_{jacket} * Asl, com, jacket + Es_{core} * Asl, com, core) / Asl, com = 200000.00$   
 $y_v = 0.00152175$   
 $sh_v = 0.0048696$   
 $ft_v = 507.2537$   
 $fy_v = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou, min = lb/ld = 0.33981258$   
 $suv = 0.4 * esuv, nominal ((5.5), TBDY) = 0.032$   
 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, ASCE 41-17.  
 with  $fsv = (fs_{jacket} * Asl, mid, jacket + fs_{mid} * Asl, mid, core) / Asl, mid = 422.7114$   
 with  $Es_v = (Es_{jacket} * Asl, mid, jacket + Es_{mid} * Asl, mid, core) / Asl, mid = 200000.00$   
 $1 = Asl, ten / (b * d) * (fs_1 / f_c) = 0.0752324$   
 $2 = Asl, com / (b * d) * (fs_2 / f_c) = 0.0752324$   
 $v = Asl, mid / (b * d) * (fsv / f_c) = 0.02812438$   
 and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl, ten / (b * d) * (fs_1 / f_c) = 0.09371431$   
 $2 = Asl, com / (b * d) * (fs_2 / f_c) = 0.09371431$   
 $v = Asl, mid / (b * d) * (fsv / f_c) = 0.03503353$

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

--->  
v < vs,y2 - LHS eq.(4.5) is satisfied  
--->  
su (4.9) = 0.16791801  
Mu = MRc (4.14) = 2.2193E+008  
u = su (4.1) = 1.9632832E-005

Calculation of ratio lb/l<sub>d</sub>

Lap Length: lb/l<sub>d</sub> = 0.33981258  
lb = 300.00  
ld = 882.8396  
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
= 1  
db = 16.66667  
Mean strength value of all re-bars: fy = 655.558  
Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)  
t = 1.00  
s = 0.80  
e = 1.00  
cb = 25.00  
Ktr = 2.86234  
Atr = Min(Atr\_x,Atr\_y) = 257.6106  
where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y loxal axis  
s = Max(s\_external,s\_internal) = 300.00  
n = 12.00

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:  
u = 1.9632832E-005  
Mu = 2.2193E+008

with full section properties:

b = 450.00  
d = 407.00  
d' = 43.00  
v = 0.00124204  
N = 7506.808  
fc = 33.00  
co (5A.5, TBDY) = 0.002  
Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01393923  
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY: cu = 0.01393923  
we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+Min( fx, fy) = 0.06811101  
where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.06628267  
af = 0.54930041  
b = 450.00  
h = 450.00  
From EC8 A4.4.3(6), pf = 2tf/bw = 0.00451556  
bw = 450.00  
effective stress from (A.35), ffe = 881.8461

fy = 0.06628267  
af = 0.54930041  
b = 450.00  
h = 450.00

From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $ff,e = 881.8461$

$R = 40.00$   
Effective FRP thickness,  $tf = NL*t*\cos(b1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $ase((5.4d), TBDY) = (ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.14546167$   
 $ase1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi2_1 = 608400.00$   
 $ase2 = \max(ase1, ase2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi2_2 = 234256.00$   
 $psh_{,min}*F_{ywe} = \min(psh_{,x}*F_{ywe}, psh_{,y}*F_{ywe}) = 1.38262$

Expression ((5.4d), TBDY) for  $psh_{,min}*F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x}*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 1.38262$   
 $ps1 \text{ (external)} = (Ash1*h1/s1)/A_{sec} = 0.00116355$   
 $Ash1 = Astir_1*ns_1 = 157.0796$   
No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2*h2/s2)/A_{sec} = 0.00103427$   
 $Ash2 = Astir_2*ns_2 = 100.531$   
No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

$psh_{,y}*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 1.38262$   
 $ps1 \text{ (external)} = (Ash1*h1/s1)/A_{sec} = 0.00116355$   
 $Ash1 = Astir_1*ns_1 = 157.0796$   
No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2*h2/s2)/A_{sec} = 0.00103427$   
 $Ash2 = Astir_2*ns_2 = 100.531$   
No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

$A_{sec} = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$

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

$lo/lou, \min = lb/ld = 0.33981258$   
 $su1 = 0.4*esu1_{nominal}((5.5), TBDY) = 0.032$

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, ASCE 41-17.

with  $fs1 = (fs_{jacket}*A_{sl,ten,jacket} + fs_{core}*A_{sl,ten,core})/A_{sl,ten} = 399.8226$

with  $Es1 = (Es_{jacket}*A_{sl,ten,jacket} + Es_{core}*A_{sl,ten,core})/A_{sl,ten} = 200000.00$

$y2 = 0.00152175$



```

sh2 = 0.0048696
ft2 = 479.7871
fy2 = 399.8226
su2 = 0.0066488
    using (30) in Biskinis/Fardis (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 = 0.33981258
    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, ASCE 41-17.
    with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226
    with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
    yv = 0.00152175
    shv = 0.0048696
    ftv = 507.2537
    fyv = 422.7114
    suv = 0.0066488
    using (30) in Biskinis/Fardis (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 = 0.33981258
    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, ASCE 41-17.
    with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
    2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
    v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438
    and confined core properties:
    b = 390.00
    d = 377.00
    d' = 13.00
    fcc (5A.2, TBDY) = 36.47874
    cc (5A.5, TBDY) = 0.00305417
    c = confinement factor = 1.10542
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
    2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
    v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353
    Case/Assumption: Unconfined full section - Steel rupture
    ' satisfies Eq. (4.3)
    --->
    v < vs,y2 - LHS eq.(4.5) is satisfied
    --->
    su (4.9) = 0.16791801
    Mu = MRc (4.14) = 2.2193E+008
    u = su (4.1) = 1.9632832E-005

```

#### Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.33981258
lb = 300.00
lb = 882.8396
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.98765, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00

```

$s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $Ktr = 2.86234$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$   
 $n = 12.00$

Calculation of Shear Strength  $Vr = \text{Min}(Vr1, Vr2) = 567563.724$

Calculation of Shear Strength at edge 1,  $Vr1 = 567563.724$

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

$VCol0 = 567563.724$

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

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

$= 1$  (normal-weight concrete)

Mean concrete strength:  $fc' = (fc'_{\text{jacket}} * Area_{\text{jacket}} + fc'_{\text{core}} * Area_{\text{core}}) / Area_{\text{section}} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$Mu = 1.0463738E-012$

$Vu = 2.7162834E-031$

$d = 0.8 * h = 360.00$

$Nu = 7506.808$

$Ag = 202500.00$

From (11.5.4.8), ACI 318-14:  $Vs = Vs1 + Vs2 = 144280.365$

where:

$Vs1 = 69813.729$  is calculated for jacket, with:

$d = 360.00$

$Av = 157079.633$

$fy = 555.56$

$s = 300.00$

$Vs1$  is multiplied by  $Col1 = 0.66666667$

$s/d = 0.83333333$

$Vs2 = 74466.637$  is calculated for core, with:

$d = 200.00$

$Av = 100530.965$

$fy = 444.44$

$s = 120.00$

$Vs2$  is multiplied by  $Col2 = 1.00$

$s/d = 0.60$

$Vf$  ((11-3)-(11.4), ACI 440) = 214457.247

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

$Vf = \text{Min}(|Vf(45, \theta_1)|, |Vf(-45, a_1)|)$ , with:

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

$dfv = d$  (figure 11.2, ACI 440) = 407.00

$ffe$  ((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:  $Vs + Vf \leq 579413.096$

$bw = 450.00$

Calculation of Shear Strength at edge 2,  $Vr2 = 567563.724$

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

VCol0 = 567563.724

knl = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 1.0463738E-012

Vu = 2.7162834E-031

d = 0.8\*h = 360.00

Nu = 7506.808

Ag = 202500.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 144280.365

where:

Vs1 = 69813.729 is calculated for jacket, with:

d = 360.00

Av = 157079.633

fy = 555.56

s = 300.00

Vs1 is multiplied by Col1 = 0.66666667

s/d = 0.83333333

Vs2 = 74466.637 is calculated for core, with:

d = 200.00

Av = 100530.965

fy = 444.44

s = 120.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.60

Vf ((11-3)-(11.4), ACI 440) = 214457.247

f = 0.95, for fully-wrapped sections

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

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

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

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

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

total thickness per orientation,  $tf1 = NL \cdot t / \text{NoDir} = 1.016$

dfv = d (figure 11.2, ACI 440) = 407.00

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 <= 579413.096

bw = 450.00

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -2.3098E+007$

Shear Force,  $V_2 = -7697.601$

Shear Force,  $V_3 = 1.7235006E-013$

Axial Force,  $F = -7503.728$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 1137.257$

-Compression:  $As_c = 1539.38$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

-Middle:  $As_{mid} = 402.1239$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

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

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

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

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten,core} = 307.8761$

-Compression:  $As_{c,com,core} = 307.8761$

-Middle:  $As_{mid,core} = 0.00$

Mean Diameter of Tension Reinforcement,  $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = * u = 0.00552671$

$u = y + p = 0.00650201$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00650201$  ((4.29), Biskinis Phd))  
 $M_y = 1.7613E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3000.708  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.7095E+013$   
 $factor = 0.30$   
 $A_g = 202500.00$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$   
 $N = 7503.728$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 9.0315E+013$

#### Calculation of Yielding Moment $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 6.1806747E-006$   
 with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 374.3546$   
 $d = 407.00$   
 $y = 0.25591435$   
 $A = 0.0147239$   
 $B = 0.00818869$   
 with  $p_t = 0.00430549$   
 $p_c = 0.00620943$   
 $p_v = 0.0021956$   
 $N = 7503.728$   
 $b = 450.00$   
 $" = 0.10565111$   
 $y_{comp} = 2.2127278E-005$   
 with  $f_c' (12.3, (ACI 440)) = 34.40847$   
 $f_c = 33.00$   
 $f_l = 0.82797802$   
 $b = 450.00$   
 $h = 450.00$   
 $A_g = 202500.00$   
 From (12.9), ACI 440:  $k_a = 0.54261599$   
 $g = p_t + p_c + p_v = 0.01461445$   
 $r_c = 40.00$   
 $A_e / A_c = 0.54261599$   
 Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.25471862$   
 $A = 0.01452515$   
 $B = 0.00807924$   
 with  $E_s = 200000.00$

#### Calculation of ratio $I_b / I_d$

Lap Length:  $I_d / I_{d,min} = 0.42476573$

$I_b = 300.00$

$I_d = 706.2717$

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

= 1

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$   
 where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$   
 $n = 12.00$

- Calculation of  $p$  -

From table 10-8:  $p = 0.00$

with:

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

shear control ratio  $V_y E / V_{Col} O E = 0.26068017$

$d = d_{\text{external}} = 407.00$

$s = s_{\text{external}} = 0.00$

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00430549$

jacket:  $s_1 = A_{v1} \cdot h_1 / (s_1 \cdot A_g) = 0.00116355$

$A_{v1} = 157.0796$ , is the total area of all stirrups parallel to loading (shear) direction

$h_1 = 450.00$

$s_1 = 300.00$

core:  $s_2 = A_{v2} \cdot h_2 / (s_2 \cdot A_g) = 0.00103427$

$A_{v2} = 100.531$ , is the total area of all stirrups parallel to loading (shear) direction

$h_2 = 250.00$

$s_2 = 120.00$

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.

For the normalisation  $f_s$  of jacket is used.

$NUD = 7503.728$

$A_g = 202500.00$

$f_{cE} = (f_{c\_jacket} \cdot \text{Area\_jacket} + f_{c\_core} \cdot \text{Area\_core}) / \text{section\_area} = 28.98765$

$f_{yIE} = (f_{y\_ext\_Long\_Reinf} \cdot \text{Area\_ext\_Long\_Reinf} + f_{y\_int\_Long\_Reinf} \cdot \text{Area\_int\_Long\_Reinf}) / \text{Area\_Tot\_Long\_Rein} = 529.9972$

$f_{ytE} = (f_{y\_ext\_Trans\_Reinf} \cdot s_1 + f_{y\_int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 503.2682$

$\rho_l = \text{Area\_Tot\_Long\_Rein} / (b \cdot d) = 0.01461445$

$b = 450.00$

$d = 407.00$

$f_{cE} = 28.98765$

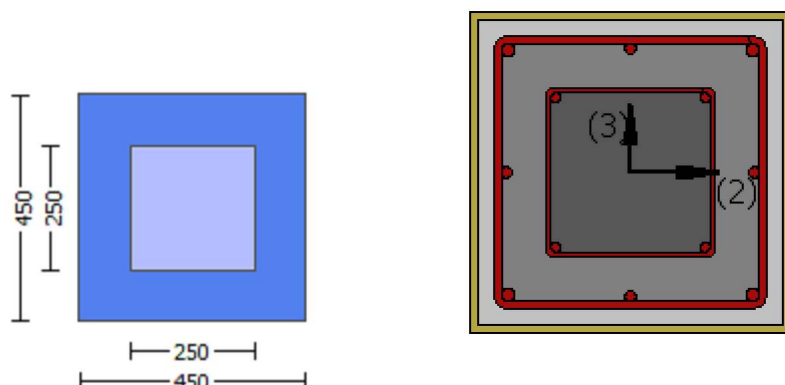
End Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

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 JC1 of floor 1  
 At local axis: 2  
 Integration Section: (b)  
 Section Type: rcjrs

#### Constant Properties

Knowledge Factor,  $\gamma = 0.85$   
 Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.  
 Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 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, ASCE 41-17) because bending is considered as  
 Deformation-Controlled Action (Table C7-1, ASCE 41-17).  
 Jacket  
 New material: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Existing Column  
 Existing material: Concrete Strength,  $f_c = f_{cm} = 20.00$   
 Existing material: Steel Strength,  $f_s = f_{sm} = 444.44$   
 #####  
 External Height,  $H = 450.00$   
 External Width,  $W = 450.00$   
 Internal Height,  $H = 250.00$   
 Internal Width,  $W = 250.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Primary Member

Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_o = l_b = 300.00$   
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $\epsilon_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i: 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

EDGE -A-  
 Bending Moment,  $M_a = -2.3098E+007$   
 Shear Force,  $V_a = -7697.601$   
 EDGE -B-  
 Bending Moment,  $M_b = 0.06012619$   
 Shear Force,  $V_b = 7697.601$   
 BOTH EDGES  
 Axial Force,  $F = -7503.728$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{sl,t} = 0.00$   
   -Compression:  $A_{sl,c} = 2676.637$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{sl,ten} = 1137.257$   
   -Compression:  $A_{sl,com} = 1137.257$   
   -Middle:  $A_{sl,mid} = 402.1239$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = V_n = 447100.515$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{CoI} = 526000.605$   
 $V_{CoI} = 526000.605$   
 $k_n = 1.00$   
 $displacement\_ductility\_demand = 0.19669705$

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)  
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 22.22222$ , but  $f_c'^{0.5} \leq 8.3$  MPa ((22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 0.06012619$   
 $V_u = 7697.601$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7503.728$   
 $A_g = 202500.00$   
 From ((11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 129852.496$   
 where:  
 $V_{s1} = 62831.853$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$



Vs2 = 67020.643 is calculated for core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 400.00$$

$$s = 120.00$$

Vs2 is multiplied by Col2 = 1.00

$$s/d = 0.60$$

$$V_f((11-3)-(11.4), \text{ACI 440}) = 214457.247$$

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.

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

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

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

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 407.00$$

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 507312.442$$

$$b_w = 450.00$$

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  $\theta = 0.00012786$

$$y = (M_y * L_s / 3) / E_{\text{eff}} = 0.00065005 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 1.7613\text{E}+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 300.00$$

$$\text{From table 10.5, ASCE 41_17: } E_{\text{eff}} = \text{factor} * E_c * I_g = 2.7095\text{E}+013$$

$$\text{factor} = 0.30$$

$$A_g = 202500.00$$

$$\text{Mean concrete strength: } f'_c = (f'_c_{\text{jacket}} * A_{\text{jacket}} + f'_c_{\text{core}} * A_{\text{core}}) / A_{\text{section}} = 28.98765$$

$$N = 7503.728$$

$$E_c * I_g = E_{c_{\text{jacket}}} * I_{g_{\text{jacket}}} + E_{c_{\text{core}}} * I_{g_{\text{core}}} = 9.0315\text{E}+013$$

Calculation of Yielding Moment  $M_y$

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

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

$$y_{\text{ten}} = 6.1806747\text{E}-006$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 374.3546$$

$$d = 407.00$$

$$y = 0.25591435$$

$$A = 0.0147239$$

$$B = 0.00818869$$

$$\text{with } p_t = 0.00620943$$

$$p_c = 0.00620943$$

$$p_v = 0.0021956$$

$$N = 7503.728$$

$$b = 450.00$$

$$\mu = 0.10565111$$

$$y_{\text{comp}} = 2.2127278\text{E}-005$$

$$\text{with } f'_c * (12.3, (\text{ACI 440})) = 34.40847$$

$$f_c = 33.00$$

$$f_l = 0.82797802$$

$$b = 450.00$$

$h = 450.00$   
 $A_g = 202500.00$   
 From (12.9), ACI 440:  $k_a = 0.54261599$   
 $g = p_t + p_c + p_v = 0.01461445$   
 $rc = 40.00$   
 $A_e/A_c = 0.54261599$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.25471862$   
 $A = 0.01452515$   
 $B = 0.00807924$   
 with  $E_s = 200000.00$

Calculation of ratio  $I_b/I_d$

Lap Length:  $I_d/I_{d,min} = 0.42476573$

$I_b = 300.00$

$I_d = 706.2717$

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

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 257.6106$

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

$s = \max(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

End Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 6

column C1, Floor 1

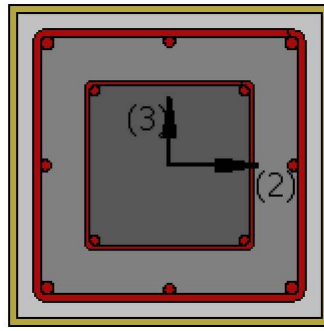
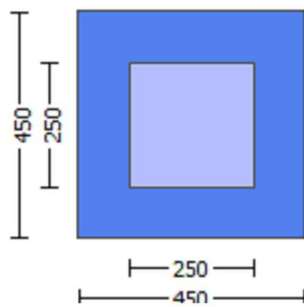
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\phi_r$ )

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

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

#####

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

## Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 2.0531359E-031$

EDGE -B-

Shear Force,  $V_b = -2.0531359E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_{lt} = 0.00$

-Compression:  $As_{lc} = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$   
with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.2193E+008$

$Mu_{1+} = 2.2193E+008$ , 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

$Mu_{1-} = 2.2193E+008$ , 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.2193E+008$

$Mu_{2+} = 2.2193E+008$ , 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

$Mu_{2-} = 2.2193E+008$ , 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:

$\phi_u = 1.9632832E-005$

$M_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

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

Final value of  $\phi_{cu}$ :  $\phi_{cu}^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01393923$

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

From (5.4b), TBDY:  $\phi_{cu} = 0.01393923$

we ((5.4c), TBDY)  $= a_s e * \text{sh}, \min(f_{ywe}/f_{ce} + \text{Min}(f_x, f_y)) = 0.06811101$

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

$f_x = 0.06628267$

$a_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$f_y = 0.06628267$   
 $a_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
 From EC8 A4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$   
 $b_w = 450.00$   
 effective stress from (A.35),  $f_{f,e} = 881.8461$

$R = 40.00$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_f = 0.015$   
 $a_{se} ((5.4d), TBDY) = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int}) / A_{sec} = 0.14546167$   
 $a_{se1} = 0.12623274$   
 $b_{o,1} = 390.00$   
 $h_{o,1} = 390.00$   
 $b_{i2,1} = 608400.00$   
 $a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$   
 $b_{o,2} = 242.00$   
 $h_{o,2} = 242.00$   
 $b_{i2,2} = 234256.00$   
 $p_{sh,min} \cdot F_{ywe} = \text{Min}(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 1.38262$

Expression ((5.4d), TBDY) for  $p_{sh,min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 1.38262$   
 $p_{s1} \text{ (external)} = (A_{sh1} \cdot h_1 / s_1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir,1} \cdot n_{s,1} = 157.0796$   
 No stirrups,  $n_{s,1} = 2.00$   
 $h_1 = 450.00$   
 $p_{s2} \text{ (internal)} = (A_{sh2} \cdot h_2 / s_2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir,2} \cdot n_{s,2} = 100.531$   
 No stirrups,  $n_{s,2} = 2.00$   
 $h_2 = 250.00$

$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 1.38262$   
 $p_{s1} \text{ (external)} = (A_{sh1} \cdot h_1 / s_1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir,1} \cdot n_{s,1} = 157.0796$   
 No stirrups,  $n_{s,1} = 2.00$   
 $h_1 = 450.00$   
 $p_{s2} \text{ (internal)} = (A_{sh2} \cdot h_2 / s_2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir,2} \cdot n_{s,2} = 100.531$   
 No stirrups,  $n_{s,2} = 2.00$   
 $h_2 = 250.00$

$A_{sec} = 202500.00$   
 $s_1 = 300.00$   
 $s_2 = 120.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $c_c = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y_1 = 0.00152175$   
 $sh_1 = 0.0048696$   
 $ft_1 = 479.7871$   
 $fy_1 = 399.8226$   
 $su_1 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $l_o/l_{ou,min} = l_b/l_d = 0.33981258$   
 $su_1 = 0.4 \cdot esu_{1,nominal} ((5.5), TBDY) = 0.032$   
 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  $f_{sy1} = f_{s1}/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $f_{s1} = (f_{sjacket} \cdot A_{s,ten,jacket} + f_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 399.8226$   
with  $E_{s1} = (E_{sjacket} \cdot A_{s,ten,jacket} + E_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.33981258$   
 $su2 = 0.4 \cdot esu2_{nominal} ((5.5), \text{TBDY}) = 0.032$   
From table 5A.1, TBDY:  $esu2_{nominal} = 0.08$ ,  
For calculation of  $esu2_{nominal}$  and  $y2, sh2, ft2, fy2$ , it is considered  
characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $f_{s2} = (f_{sjacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core})/A_{s,com} = 399.8226$   
with  $E_{s2} = (E_{sjacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core})/A_{s,com} = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.33981258$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), \text{TBDY}) = 0.032$   
From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv_{nominal}$  and  $yv, shv, ftv, fyv$ , it is considered  
characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $f_{sv} = (f_{sjacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 422.7114$   
with  $E_{sv} = (E_{sjacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 200000.00$   
 $1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0752324$   
 $2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0752324$   
 $v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, \text{TBDY}) = 36.47874$   
 $cc (5A.5, \text{TBDY}) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.09371431$   
 $2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09371431$   
 $v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$   
 $l_b = 300.00$   
 $l_d = 882.8396$

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

$db = 16.66667$   
Mean strength value of all re-bars:  $fy = 655.558$   
Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$   
where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \max(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$

#### Calculation of $\mu_1$ -

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

$\mu = 1.9632832E-005$

$\mu_1 = 2.2193E+008$

with full section properties:

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.00124204$   
 $N = 7506.808$   
 $fc = 33.00$   
 $\alpha_1$  (5A.5, TBDY) = 0.002  
Final value of  $\mu_1$ :  $\mu_1^* = \text{shear\_factor} \cdot \max(\mu_1, \mu_2) = 0.01393923$   
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY:  $\mu_1 = 0.01393923$   
 $\mu_2$  ((5.4c), TBDY) =  $\alpha_1 \cdot \min(f_{ywe}/f_{ce} + \min(f_x, f_y)) = 0.06811101$   
where  $f = \alpha_1 \cdot p_f \cdot f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06628267$   
 $\alpha_1 = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $f_{fe} = 881.8461$

$f_y = 0.06628267$   
 $\alpha_1 = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $f_{fe} = 881.8461$

$R = 40.00$   
Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u, f = 0.015$   
 $\alpha_{se}$  ((5.4d), TBDY) =  $(\alpha_{se1} \cdot A_{ext} + \alpha_{se2} \cdot A_{int}) / A_{sec} = 0.14546167$   
 $\alpha_{se1} = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi_2 = 608400.00$   
 $\alpha_{se2} = \max(\alpha_{se1}, \alpha_{se2}) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$

```

bi2_2 = 234256.00
psh,min*Fywe = Min(psh,x*Fywe , psh,y*Fywe) = 1.38262
Expression ((5.4d), TBDY) for psh,min*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without
earthquake detailing (90° closed stirrups)
-----
psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 1.38262
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00116355
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 450.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00103427
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 250.00
-----
psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 1.38262
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00116355
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 450.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00103427
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 250.00
-----
Asec = 202500.00
s1 = 300.00
s2 = 120.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00
From ((5.A5), TBDY), TBDY: cc = 0.00305417
c = confinement factor = 1.10542
y1 = 0.00152175
sh1 = 0.0048696
ft1 = 479.7871
fy1 = 399.8226
su1 = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.33981258
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, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 399.8226
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00152175
sh2 = 0.0048696
ft2 = 479.7871
fy2 = 399.8226
su2 = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.33981258
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, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00152175
shv = 0.0048696

```



```

ftv = 507.2537
fyv = 422.7114
suv = 0.0066488
    using (30) in Biskinis/Fardis (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 = 0.33981258
    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, ASCE 41-17.
    with fsv = (fsjacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
    2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
    v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
    c = confinement factor = 1.10542
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
    2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
    v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008
u = su (4.1) = 1.9632832E-005
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.33981258
lb = 300.00
ld = 882.8396
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.98765, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.86234
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 300.00
n = 12.00
-----
-----
-----
Calculation of Mu2+
-----
-----
-----
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.9632832E-005

```

$$\mu = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, \alpha) = 0.01393923$$

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

$$\text{From (5.4b), TB DY: } \mu = 0.01393923$$

$$\mu_e ((5.4c), \text{TB DY}) = \alpha * \mu_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

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

$$f_x = 0.06628267$$

$$\alpha f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_f = 2t_f/bw = 0.00451556$$

$$bw = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$f_y = 0.06628267$$

$$\alpha f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_f = 2t_f/bw = 0.00451556$$

$$bw = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

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

$$\alpha_e ((5.4d), \text{TB DY}) = (\alpha_e1 * A_{ext} + \alpha_e2 * A_{int}) / A_{sec} = 0.14546167$$

$$\alpha_e1 = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i2,1} = 608400.00$$

$$\alpha_e2 = \text{Max}(\alpha_e1, \alpha_e2) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i2,2} = 234256.00$$

$$\mu_{\min} * f_{ywe} = \text{Min}(\mu_{\min,x} * f_{ywe}, \mu_{\min,y} * f_{ywe}) = 1.38262$$

Expression ((5.4d), TB DY) for  $\mu_{\min} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\mu_{\min,x} * f_{ywe} = \mu_{\min,1} * f_{ywe1} + \mu_{\min,2} * f_{ywe2} = 1.38262$$

$$\mu_{\min,1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{\text{stir}_1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$\mu_{\min,2} (\text{internal}) = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{\text{stir}_2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h_2 = 250.00$$

$$\mu_{\min,y} * f_{ywe} = \mu_{\min,1} * f_{ywe1} + \mu_{\min,2} * f_{ywe2} = 1.38262$$

$$\mu_{\min,1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{\text{stir}_1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$\mu_{\min,2} (\text{internal}) = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{\text{stir}_2} * n_{s,2} = 100.531$$

No stirrups, ns\_2 = 2.00  
h2 = 250.00

Asec = 202500.00

s1 = 300.00

s2 = 120.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5A5), TBDY), TBDY: cc = 0.00305417

c = confinement factor = 1.10542

y1 = 0.00152175

sh1 = 0.0048696

ft1 = 479.7871

fy1 = 399.8226

su1 = 0.0066488

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

lo/lou,min = lb/lb = 0.33981258

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, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175

sh2 = 0.0048696

ft2 = 479.7871

fy2 = 399.8226

su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.33981258

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, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 399.8226

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00152175

shv = 0.0048696

ftv = 507.2537

fyv = 422.7114

suv = 0.0066488

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

lo/lou,min = lb/lb = 0.33981258

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, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 422.7114

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0752324

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.0752324

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.02812438

and confined core properties:

b = 390.00

d = 377.00

d' = 13.00

$f_{cc}$  (5A.2, TBDY) = 36.47874  
 $\alpha$  (5A.5, TBDY) = 0.00305417  
 $\alpha$  = confinement factor = 1.10542  
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.09371431$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09371431$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03503353$   
 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) = 0.16791801  
 $\mu_u = M_{Rc}$  (4.14) = 2.2193E+008  
 $u = \mu_u$  (4.1) = 1.9632832E-005

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$   
 $l_b = 300.00$   
 $l_d = 882.8396$   
 Calculation of  $l_b$ ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 655.558$   
 Mean concrete strength:  $f'_c = (f'_c_{jacket} * Area_{jacket} + f'_c_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \max(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$

Calculation of  $\mu_{u2}$

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 1.9632832E-005$   
 $\mu_u = 2.2193E+008$

with full section properties:

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.00124204$   
 $N = 7506.808$   
 $f_c = 33.00$   
 $\alpha$  (5A.5, TBDY) = 0.002  
 Final value of  $\mu_u$ :  $\mu_u^* = shear\_factor * \max(\mu_u, \alpha) = 0.01393923$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\mu_u = 0.01393923$   
 $\mu_u$  ((5.4c), TBDY) =  $\alpha * sh_{min} * f_{ywe}/f_{ce} + \min(f_x, f_y) = 0.06811101$   
 where  $f = \alpha * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)  
 $f_x = 0.06628267$   
 $\alpha_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$   
 $bw = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$f_y = 0.06628267$

$a_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$a_{se} ((5.4d), TBDY) = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int}) / A_{sec} = 0.14546167$

$a_{se1} = 0.12623274$

$bo_1 = 390.00$

$ho_1 = 390.00$

$bi2_1 = 608400.00$

$a_{se2} = \max(a_{se1}, a_{se2}) = 0.18853448$

$bo_2 = 242.00$

$ho_2 = 242.00$

$bi2_2 = 234256.00$

$p_{sh,min} \cdot F_{ywe} = \min(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 1.38262$

Expression ((5.4d), TBDY) for  $p_{sh,min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{s2} \cdot F_{ywe2} = 1.38262$

$p_{s1} \text{ (external)} = (A_{sh1} \cdot h_1 / s_1) / A_{sec} = 0.00116355$

$A_{sh1} = A_{stir_1} \cdot n_{s_1} = 157.0796$

No stirrups,  $n_{s_1} = 2.00$

$h_1 = 450.00$

$p_{s2} \text{ (internal)} = (A_{sh2} \cdot h_2 / s_2) / A_{sec} = 0.00103427$

$A_{sh2} = A_{stir_2} \cdot n_{s_2} = 100.531$

No stirrups,  $n_{s_2} = 2.00$

$h_2 = 250.00$

$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{s2} \cdot F_{ywe2} = 1.38262$

$p_{s1} \text{ (external)} = (A_{sh1} \cdot h_1 / s_1) / A_{sec} = 0.00116355$

$A_{sh1} = A_{stir_1} \cdot n_{s_1} = 157.0796$

No stirrups,  $n_{s_1} = 2.00$

$h_1 = 450.00$

$p_{s2} \text{ (internal)} = (A_{sh2} \cdot h_2 / s_2) / A_{sec} = 0.00103427$

$A_{sh2} = A_{stir_2} \cdot n_{s_2} = 100.531$

No stirrups,  $n_{s_2} = 2.00$

$h_2 = 250.00$

$A_{sec} = 202500.00$

$s_1 = 300.00$

$s_2 = 120.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$

$c$  = confinement factor = 1.10542

$y_1 = 0.00152175$

$sh_1 = 0.0048696$

$ft_1 = 479.7871$

$fy_1 = 399.8226$

$su_1 = 0.0066488$

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

$lo/lou,min = lb/ld = 0.33981258$

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

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

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs1 = (fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 399.8226$   
with  $Es1 = (Es_{jacket} \cdot Asl_{ten,jacket} + Es_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $lo/lo_{ou,min} = lb/lb_{min} = 0.33981258$   
 $su2 = 0.4 \cdot esu2\_nominal \cdot ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 399.8226$   
with  $Es2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $lo/lo_{ou,min} = lb/ld = 0.33981258$   
 $suv = 0.4 \cdot esuv\_nominal \cdot ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 422.7114$   
with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs1/fc) = 0.0752324$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs2/fc) = 0.0752324$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv/fc) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs1/fc) = 0.09371431$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs2/fc) = 0.09371431$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv/fc) = 0.03503353$

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

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
--->  
 $su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.33981258$   
 $lb = 300.00$   
 $ld = 882.8396$   
Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$\lambda = 1$   
 $db = 16.66667$   
Mean strength value of all re-bars:  $f_y = 655.558$   
Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot Area\_jacket + f'_{c\_core} \cdot Area\_core) / Area\_section = 28.98765$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \min(A_{tr\_x}, A_{tr\_y}) = 257.6106$   
where  $A_{tr\_x}, A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \max(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$

Calculation of Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 567563.724$

Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$V_{Col0} = 567563.724$

$k_{nl} = 1$  (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)  
Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot Area\_jacket + f'_{c\_core} \cdot Area\_core) / Area\_section = 28.98765$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.4404090E-011$   
 $\nu_u = 2.0531359E-031$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f ((11-3)-(11.4), ACI 440) = 214457.247$   
 $f = 0.95$ , 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,  $t_{f1} = N_L \cdot t / NoDir = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $bw = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$   
 $V_{Col0} = 567563.724$   
 $knl = 1$  (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)  
Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M / Vd = 2.00$   
 $\mu_u = 1.4404090E-011$   
 $V_u = 2.0531359E-031$   
 $d = 0.8 * h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f ((11-3)-(11.4), ACI 440) = 214457.247$   
 $f = 0.95$ , 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) = 407.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
with  $f_u = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $bw = 450.00$

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjrs



## Constant Properties

Knowledge Factor,  $\phi = 0.85$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

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

#####

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

## Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = -2.7162834E-031$

EDGE -B-

Shear Force,  $V_b = 2.7162834E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$   
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 2.2193\text{E}+008$

$\mu_{1+} = 2.2193\text{E}+008$ , 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

$\mu_{1-} = 2.2193\text{E}+008$ , 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 2.2193\text{E}+008$

$\mu_{2+} = 2.2193\text{E}+008$ , 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

$\mu_{2-} = 2.2193\text{E}+008$ , 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  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 1.9632832\text{E}-005$

$M_u = 2.2193\text{E}+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

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

Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01393923$

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

From (5.4b), TBDY:  $\mu_c = 0.01393923$

$\mu_{cc}$  ((5.4c), TBDY) =  $\alpha \epsilon_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.06811101$

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

$\mu_{fx} = 0.06628267$

$\alpha f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$\mu_{fy} = 0.06628267$

$\alpha f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{f,f} = 0.015$

$\alpha \epsilon$  ((5.4d), TBDY) =  $(\alpha \epsilon_1 * A_{ext} + \alpha \epsilon_2 * A_{int}) / A_{sec} = 0.14546167$

$\alpha \epsilon_1 = 0.12623274$

$b_{o,1} = 390.00$

$h_{o,1} = 390.00$

$b_{i2,1} = 608400.00$

$ase2 = \text{Max}(ase1, ase2) = 0.18853448$   
 $bo\_2 = 242.00$   
 $ho\_2 = 242.00$   
 $bi2\_2 = 234256.00$   
 $psh, \min * Fywe = \text{Min}(psh, x * Fywe, psh, y * Fywe) = 1.38262$   
 Expression ((5.4d), TBDY) for  $psh, \min * Fywe$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh\_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 * ns\_1 = 157.0796$   
 No stirrups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 * ns\_2 = 100.531$   
 No stirrups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$psh\_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 * ns\_1 = 157.0796$   
 No stirrups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 * ns\_2 = 100.531$   
 No stirrups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$Asec = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/ld = 0.33981258$   
 $su1 = 0.4 * esu1\_nominal \text{ ((5.5), TBDY)} = 0.032$   
 From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
 For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1 / 1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs1 = (fs, \text{jacket} * Asl, \text{ten, jacket} + fs, \text{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 399.8226$   
 with  $Es1 = (Es, \text{jacket} * Asl, \text{ten, jacket} + Es, \text{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/lb, \min = 0.33981258$   
 $su2 = 0.4 * esu2\_nominal \text{ ((5.5), TBDY)} = 0.032$   
 From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
 For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2 / 1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs2 = (fs, \text{jacket} * Asl, \text{com, jacket} + fs, \text{core} * Asl, \text{com, core}) / Asl, \text{com} = 399.8226$

```

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00152175
shv = 0.0048696
ftv = 507.2537
fyv = 422.7114
suv = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258
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, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
c = confinement factor = 1.10542
1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008
u = su (4.1) = 1.9632832E-005
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.33981258
lb = 300.00
ld = 882.8396
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.98765, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.86234
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 300.00
n = 12.00
-----
-----
-----
Calculation of Mu1-
-----

```

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

$$u = 1.9632832E-005$$

$$Mu = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$\phi_0 (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01393923$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.01393923$$

$$\phi_{ue} ((5.4c), TBDY) = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.06811101$$

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

$$\phi_{fx} = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$\phi_{fy} = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$a_{se1} = 0.12623274$$

$$b_{o\_1} = 390.00$$

$$h_{o\_1} = 390.00$$

$$b_{i2\_1} = 608400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$$

$$b_{o\_2} = 242.00$$

$$h_{o\_2} = 242.00$$

$$b_{i2\_2} = 234256.00$$

$$\phi_{sh, \min} * f_{ywe} = \text{Min}(\phi_{sh, x} * f_{ywe}, \phi_{sh, y} * f_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $\phi_{sh, \min} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\phi_{sh, x} * f_{ywe} = \phi_{sh1} * f_{ywe1} + \phi_{sh2} * f_{ywe2} = 1.38262$$

$$\phi_{sh1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir\_1} * n_{s\_1} = 157.0796$$

$$\text{No stirrups, } n_{s\_1} = 2.00$$

$$h_1 = 450.00$$

$$\phi_{sh2} (\text{internal}) = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir\_2} * n_{s\_2} = 100.531$$

$$\text{No stirrups, } n_{s\_2} = 2.00$$

$$h_2 = 250.00$$

$$\phi_{sh, y} * f_{ywe} = \phi_{sh1} * f_{ywe1} + \phi_{sh2} * f_{ywe2} = 1.38262$$

$$\phi_{sh1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir\_1} * n_{s\_1} = 157.0796$$

$$\text{No stirrups, } n_{s\_1} = 2.00$$

$h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 \cdot ns\_2 = 100.531$   
 $No \text{ stirups, } ns\_2 = 2.00$   
 $h2 = 250.00$

$Asec = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$

$fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$   
 $sh1 = 0.0048696$

$ft1 = 479.7871$

$fy1 = 399.8226$

$su1 = 0.0066488$

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

$lo/lou, min = lb/ld = 0.33981258$

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

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

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs\_jacket \cdot Asl, ten, jacket + fs\_core \cdot Asl, ten, core) / Asl, ten = 399.8226$

with  $Es1 = (Es\_jacket \cdot Asl, ten, jacket + Es\_core \cdot Asl, ten, core) / Asl, ten = 200000.00$

$y2 = 0.00152175$

$sh2 = 0.0048696$

$ft2 = 479.7871$

$fy2 = 399.8226$

$su2 = 0.0066488$

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

$lo/lou, min = lb/lb, min = 0.33981258$

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

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs\_jacket \cdot Asl, com, jacket + fs\_core \cdot Asl, com, core) / Asl, com = 399.8226$

with  $Es2 = (Es\_jacket \cdot Asl, com, jacket + Es\_core \cdot Asl, com, core) / Asl, com = 200000.00$

$yv = 0.00152175$

$shv = 0.0048696$

$ftv = 507.2537$

$fyv = 422.7114$

$suv = 0.0066488$

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

$lo/lou, min = lb/ld = 0.33981258$

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

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, ASCE 41-17.

with  $fsv = (fs\_jacket \cdot Asl, mid, jacket + fs\_mid \cdot Asl, mid, core) / Asl, mid = 422.7114$

with  $Esu = (Es\_jacket \cdot Asl, mid, jacket + Es\_mid \cdot Asl, mid, core) / Asl, mid = 200000.00$

$1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.0752324$

$2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.0752324$

$v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.09371431$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09371431$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$   
 $l_b = 300.00$   
 $l_d = 882.8396$   
 Calculation of  $l_b$ ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 655.558$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$

Calculation of  $Mu_{2+}$

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

$u = 1.9632832E-005$   
 $Mu = 2.2193E+008$

with full section properties:

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.00124204$   
 $N = 7506.808$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01393923$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01393923$   
 $w_e ((5.4c), TBDY) = a_{se} * sh_{min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$   
 where  $f = a_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)  
 $f_x = 0.06628267$   
 $a_f = 0.54930041$   
 $b = 450.00$

h = 450.00  
From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $ff,e = 881.8461$

fy = 0.06628267  
af = 0.54930041  
b = 450.00  
h = 450.00  
From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $ff,e = 881.8461$

R = 40.00  
Effective FRP thickness,  $tf = NL*t*Cos(b1) = 1.016$   
fu,f = 1055.00  
Ef = 64828.00  
u,f = 0.015  
 $ase((5.4d), TBDY) = (ase1*Aext+ase2*Aint)/Asec = 0.14546167$   
ase1 = 0.12623274  
bo\_1 = 390.00  
ho\_1 = 390.00  
bi2\_1 = 608400.00  
 $ase2 = Max(ase1,ase2) = 0.18853448$   
bo\_2 = 242.00  
ho\_2 = 242.00  
bi2\_2 = 234256.00

psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 1.38262  
Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) =  $(Ash1*h1/s1)/Asec = 0.00116355$   
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) =  $(Ash2*h2/s2)/Asec = 0.00103427$   
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) =  $(Ash1*h1/s1)/Asec = 0.00116355$   
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) =  $(Ash2*h2/s2)/Asec = 0.00103427$   
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

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



$l_o/l_{ou,min} = l_b/l_d = 0.33981258$   
 $su_1 = 0.4 \cdot esu_{1,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,  
 For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
 characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_1 = (fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 399.8226$   
 with  $Es_1 = (Es_{jacket} \cdot Asl_{ten,jacket} + Es_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 200000.00$   
 $y_2 = 0.00152175$   
 $sh_2 = 0.0048696$   
 $ft_2 = 479.7871$   
 $fy_2 = 399.8226$   
 $su_2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.33981258$   
 $su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 399.8226$   
 with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.00152175$   
 $sh_v = 0.0048696$   
 $ft_v = 507.2537$   
 $fy_v = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.33981258$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 422.7114$   
 with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.0752324$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.0752324$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.09371431$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.09371431$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$   
 $l_d = 882.8396$   
 Calculation of  $l_b$ , min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 655.558$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$   
 where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$

Calculation of  $\mu_2$ -

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

$u = 1.9632832E-005$   
 $\mu = 2.2193E+008$

with full section properties:

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.00124204$   
 $N = 7506.808$   
 $f_c = 33.00$   
 $\alpha_1 (5A.5, \text{TBDY}) = 0.002$   
 Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} \cdot \text{Max}(\mu, \mu_c) = 0.01393923$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\mu = 0.01393923$   
 $\mu_e ((5.4c), \text{TBDY}) = \alpha_1 \cdot \text{sh}_{\min} \cdot f_{ywe} / f_{ce} + \text{Min}(\mu_x, \mu_y) = 0.06811101$   
 where  $\mu = \alpha_1 \cdot p_f \cdot f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\mu_x = 0.06628267$   
 $\alpha_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$   
 $bw = 450.00$   
 effective stress from (A.35),  $f_{fe} = 881.8461$

$\mu_y = 0.06628267$   
 $\alpha_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$   
 $bw = 450.00$   
 effective stress from (A.35),  $f_{fe} = 881.8461$

$R = 40.00$   
 Effective FRP thickness,  $t_f = N \cdot t \cdot \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{f,f} = 0.015$   
 $\alpha_{se} ((5.4d), \text{TBDY}) = (\alpha_{se1} \cdot A_{ext} + \alpha_{se2} \cdot A_{int}) / A_{sec} = 0.14546167$   
 $\alpha_{se1} = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$

$bi2\_1 = 608400.00$   
 $ase2 = \text{Max}(ase1, ase2) = 0.18853448$   
 $bo\_2 = 242.00$   
 $ho\_2 = 242.00$   
 $bi2\_2 = 234256.00$   
 $psh, min * Fywe = \text{Min}(psh, x * Fywe, psh, y * Fywe) = 1.38262$   
 Expression ((5.4d), TBDY) for  $psh, min * Fywe$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh\_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 * ns\_1 = 157.0796$   
 No stirrups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 * ns\_2 = 100.531$   
 No stirrups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$psh\_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 * ns\_1 = 157.0796$   
 No stirrups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 * ns\_2 = 100.531$   
 No stirrups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$Asec = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$

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

$lo/lou, min = lb/ld = 0.33981258$

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

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

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1 / 1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs, jacket * Asl, ten, jacket + fs, core * Asl, ten, core) / Asl, ten = 399.8226$

with  $Es1 = (Es, jacket * Asl, ten, jacket + Es, core * Asl, ten, core) / Asl, ten = 200000.00$

$y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$

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

$lo/lou, min = lb/lb, min = 0.33981258$

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

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2 / 1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_2 = (fs_{\text{jacket}} \cdot Asl_{\text{com,jacket}} + fs_{\text{core}} \cdot Asl_{\text{com,core}}) / Asl_{\text{com}} = 399.8226$$

$$\text{with } Es_2 = (Es_{\text{jacket}} \cdot Asl_{\text{com,jacket}} + Es_{\text{core}} \cdot Asl_{\text{com,core}}) / Asl_{\text{com}} = 200000.00$$

$$y_v = 0.00152175$$

$$sh_v = 0.0048696$$

$$ft_v = 507.2537$$

$$fy_v = 422.7114$$

$$su_v = 0.0066488$$
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  

$$l_o/l_{o,min} = l_b/l_d = 0.33981258$$

$$su_v = 0.4 \cdot esuv_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$$
 From table 5A.1, TBDY:  $esuv_{\text{nominal}} = 0.08$ ,  
 considering characteristic value  $fs_{yv} = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{\text{nominal}}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fs_{yv} = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  

$$\text{with } fsv = (fs_{\text{jacket}} \cdot Asl_{\text{mid,jacket}} + fs_{\text{mid}} \cdot Asl_{\text{mid,core}}) / Asl_{\text{mid}} = 422.7114$$

$$\text{with } Es_v = (Es_{\text{jacket}} \cdot Asl_{\text{mid,jacket}} + Es_{\text{mid}} \cdot Asl_{\text{mid,core}}) / Asl_{\text{mid}} = 200000.00$$

$$1 = Asl_{\text{ten}} / (b \cdot d) \cdot (fs_1 / fc) = 0.0752324$$

$$2 = Asl_{\text{com}} / (b \cdot d) \cdot (fs_2 / fc) = 0.0752324$$

$$v = Asl_{\text{mid}} / (b \cdot d) \cdot (fsv / fc) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$fcc \text{ (5A.2, TBDY)} = 36.47874$$

$$cc \text{ (5A.5, TBDY)} = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = Asl_{\text{ten}} / (b \cdot d) \cdot (fs_1 / fc) = 0.09371431$$

$$2 = Asl_{\text{com}} / (b \cdot d) \cdot (fs_2 / fc) = 0.09371431$$

$$v = Asl_{\text{mid}} / (b \cdot d) \cdot (fsv / fc) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su \text{ (4.9)} = 0.16791801$$

$$Mu = MRc \text{ (4.14)} = 2.2193E+008$$

$$u = su \text{ (4.1)} = 1.9632832E-005$$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{\text{jacket}} \cdot Area_{\text{jacket}} + fc'_{\text{core}} \cdot Area_{\text{core}}) / Area_{\text{section}} = 28.98765$ , but  $fc'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

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

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$

$n = 12.00$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$

Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$V_{Col0} = 567563.724$

$k_{nl} = 1$  (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)

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 1.0463738E-012$

$\nu_u = 2.7162834E-031$

$d = 0.8 * h = 360.00$

$N_u = 7506.808$

$A_g = 202500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 300.00$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$s/d = 0.83333333$

$V_{s2} = 74466.637$  is calculated for core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 120.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.60$

$V_f ((11-3)-(11.4), ACI 440) = 214457.247$

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 407.00

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$

$b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$

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

$V_{Col0} = 567563.724$

$k_{nl} = 1$  (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)

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 1.0463738E-012$

$\nu_u = 2.7162834E-031$

$d = 0.8 \cdot h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f ((11-3)-(11.4), ACI 440) = 214457.247$   
 $f = 0.95$ , 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  $V_f(a)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $b_w = 450.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
 At local axis: 2  
 -----

-----  
 Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1  
 At local axis: 2  
 Integration Section: (b)  
 Section Type: rcjrs

Constant Properties

-----  
 Knowledge Factor,  $\phi = 0.85$   
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.  
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
 Concrete Elasticity,  $E_c = 21019.039$   
 Steel Elasticity,  $E_s = 200000.00$   
 External Height,  $H = 450.00$   
 External Width,  $W = 450.00$

Internal Height, H = 250.00  
 Internal Width, W = 250.00  
 Cover Thickness, c = 25.00  
 Element Length, L = 3000.00  
 Primary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length lb = 300.00  
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness, t = 1.016  
 Tensile Strength, ffu = 1055.00  
 Tensile Modulus, Ef = 64828.00  
 Elongation, efu = 0.01  
 Number of directions, NoDir = 1  
 Fiber orientations, bi: 0.00°  
 Number of layers, NL = 1  
 Radius of rounding corners, R = 40.00

#### Stepwise Properties

Bending Moment, M = -1.6313530E-010  
 Shear Force, V2 = 7697.601  
 Shear Force, V3 = -1.7235006E-013  
 Axial Force, F = -7503.728  
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension: Aslt = 0.00  
   -Compression: Aslc = 2676.637  
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension: Asl,ten = 1137.257  
   -Compression: Asl,com = 1137.257  
   -Middle: Asl,mid = 402.1239  
 Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
   -Tension: Asl,ten,jacket = 829.3805  
   -Compression: Asl,com,jacket = 829.3805  
   -Middle: Asl,mid,jacket = 402.1239  
 Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
   -Tension: Asl,ten,core = 307.8761  
   -Compression: Asl,com,core = 307.8761  
   -Middle: Asl,mid,core = 0.00  
 Mean Diameter of Tension Reinforcement, DbL = 16.80

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = u = 0.0027627$   
 $u = y + p = 0.00325024$

- Calculation of y -

$y = (My * Ls / 3) / E_{eff} = 0.00325024$  ((4.29), Biskinis Phd))  
 $My = 1.7613E+008$   
 $Ls = M/V$  (with  $Ls > 0.1 * L$  and  $Ls < 2 * L$ ) = 1500.00  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.7095E+013$   
 $factor = 0.30$   
 $Ag = 202500.00$   
 Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 28.98765$   
 $N = 7503.728$   
 $E_c * I_g = E_c * I_{g,jacket} + E_c * I_{g,core} = 9.0315E+013$

#### Calculation of Yielding Moment $M_y$

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

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$   
 $y_{\text{ten}} = 6.1806747\text{E-}006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/l_d)^{2/3}) = 374.3546$   
 $d = 407.00$   
 $y = 0.25591435$   
 $A = 0.0147239$   
 $B = 0.00818869$   
with  $p_t = 0.00430549$   
 $p_c = 0.00620943$   
 $p_v = 0.0021956$   
 $N = 7503.728$   
 $b = 450.00$   
 $\gamma = 0.10565111$   
 $y_{\text{comp}} = 2.2127278\text{E-}005$   
with  $f_c^* (12.3, \text{ACI } 440)) = 34.40847$   
 $f_c = 33.00$   
 $f_l = 0.82797802$   
 $b = 450.00$   
 $h = 450.00$   
 $A_g = 202500.00$   
From (12.9), ACI 440:  $k_a = 0.54261599$   
 $g = p_t + p_c + p_v = 0.01461445$   
 $r_c = 40.00$   
 $A_e/A_c = 0.54261599$   
Effective FRP thickness,  $t_f = N L \cdot t \cdot \cos(b_1) = 1.016$   
effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $\gamma = 0.25471862$   
 $A = 0.01452515$   
 $B = 0.00807924$   
with  $E_s = 200000.00$

#### Calculation of ratio $l_b/l_d$

Lap Length:  $l_d/l_d, \text{min} = 0.42476573$

$l_b = 300.00$

$l_d = 706.2717$

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

$= 1$

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

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

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$

$n = 12.00$

#### - Calculation of $p$ -

From table 10-8:  $p = 0.00$

with:

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

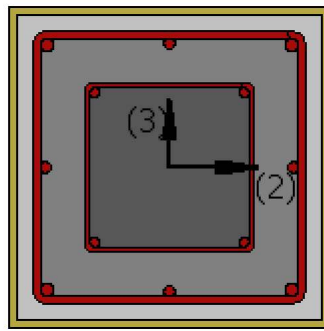
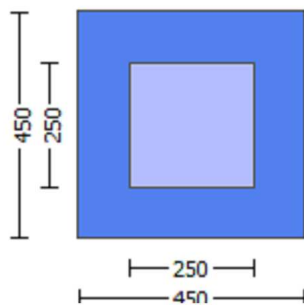


shear control ratio  $V_{yE}/V_{Col0E} = 0.26068017$   
 $d = d_{external} = 407.00$   
 $s = s_{external} = 0.00$   
 $t = s_1 + s_2 + 2 \cdot t_f/bw \cdot (f_{fe}/f_s) = 0.00430549$   
 jacket:  $s_1 = A_{v1} \cdot h_1 / (s_1 \cdot A_g) = 0.00116355$   
 $A_{v1} = 157.0796$ , is the total area of all stirrups parallel to loading (shear) direction  
 $h_1 = 450.00$   
 $s_1 = 300.00$   
 core:  $s_2 = A_{v2} \cdot h_2 / (s_2 \cdot A_g) = 0.00103427$   
 $A_{v2} = 100.531$ , is the total area of all stirrups parallel to loading (shear) direction  
 $h_2 = 250.00$   
 $s_2 = 120.00$   
 The term  $2 \cdot t_f/bw \cdot (f_{fe}/f_s)$  is implemented to account for FRP contribution  
 where  $f = 2 \cdot t_f/bw$  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.  
 For the normalisation  $f_s$  of jacket is used.  
 $NUD = 7503.728$   
 $A_g = 202500.00$   
 $f_{cE} = (f_{c,jacket} \cdot Area_{jacket} + f_{c,core} \cdot Area_{core}) / section\_area = 28.98765$   
 $f_{yE} = (f_{y,ext\_Long\_Reinf} \cdot Area_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} \cdot Area_{int\_Long\_Reinf}) / Area_{Tot\_Long\_Rein} = 529.9972$   
 $f_{yE} = (f_{y,ext\_Trans\_Reinf} \cdot s_1 + f_{y,int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 503.2682$   
 $\rho_l = Area_{Tot\_Long\_Rein} / (b \cdot d) = 0.01461445$   
 $b = 450.00$   
 $d = 407.00$   
 $f_{cE} = 28.98765$

-----  
 End Of Calculation of Chord Rotation Capacity for element: column JC1 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 JC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

New material: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material: Steel Strength,  $f_s = f_{sm} = 555.56$

Existing Column

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

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

#####

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $ef_u = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $\theta_i$ : 0.00°  
Number of layers, NL = 1  
Radius of rounding corners, R = 40.00

#### Stepwise Properties

EDGE -A-  
Bending Moment,  $M_a$  = -3.5391295E-010  
Shear Force,  $V_a$  = 1.7235006E-013  
EDGE -B-  
Bending Moment,  $M_b$  = -1.6313530E-010  
Shear Force,  $V_b$  = -1.7235006E-013  
BOTH EDGES  
Axial Force, F = -7503.728  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st}$  = 0.00  
-Compression:  $A_{sc}$  = 2676.637  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten}$  = 1137.257  
-Compression:  $A_{sc,com}$  = 1137.257  
-Middle:  $A_{sc,mid}$  = 402.1239  
Mean Diameter of Tension Reinforcement,  $D_{bL,ten}$  = 16.80

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = V_n = 447100.515$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{Col0} = 526000.605$   
 $V_{Col} = 526000.605$   
 $k_n = 1.00$   
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)  
Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 22.22222$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.6313530E-010$   
 $V_u = 1.7235006E-013$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7503.728$   
 $A_g = 202500.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 129852.496$   
where:  
 $V_{s1} = 62831.853$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 67020.643$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 400.00$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 214457.247  
 $f = 0.95$ , 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  $\alpha$  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  $\theta_i$ ,

as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
orientation 1:  $\theta_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$ , with:  
total thickness per orientation,  $t_{f1} = N_L * t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
with  $f_u = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 507312.442$   
 $b_w = 450.00$

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

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

From analysis, chord rotation  $\theta = 9.3519433E-023$   
 $y = (M_y * L_s / 3) / E_{eff} = 0.00325024$  ((4.29), Biskinis Phd))  
 $M_y = 1.7613E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 1500.00  
From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} * E_c * I_g = 2.7095E+013$   
factor = 0.30  
 $A_g = 202500.00$   
Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$   
 $N = 7503.728$   
 $E_c * I_g = E_{c,\text{jacket}} * I_{g,\text{jacket}} + E_{c,\text{core}} * I_{g,\text{core}} = 9.0315E+013$

Calculation of Yielding Moment  $M_y$

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

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$   
 $y_{\text{ten}} = 6.1806747E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 374.3546$   
 $d = 407.00$   
 $y = 0.25591435$   
 $A = 0.0147239$   
 $B = 0.00818869$   
with  $p_t = 0.00620943$   
 $p_c = 0.00620943$   
 $p_v = 0.0021956$   
 $N = 7503.728$   
 $b = 450.00$   
 $\alpha = 0.10565111$   
 $y_{\text{comp}} = 2.2127278E-005$   
with  $f_c^*$  (12.3, (ACI 440)) = 34.40847  
 $f_c = 33.00$   
 $f_l = 0.82797802$   
 $b = 450.00$   
 $h = 450.00$   
 $A_g = 202500.00$   
From (12.9), ACI 440:  $k_a = 0.54261599$   
 $g = p_t + p_c + p_v = 0.01461445$   
 $r_c = 40.00$   
 $A_e / A_c = 0.54261599$   
Effective FRP thickness,  $t_f = N_L * t * \text{Cos}(\theta_1) = 1.016$   
effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.25471862$   
 $A = 0.01452515$

B = 0.00807924  
with Es = 200000.00

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_d/l_{d,min} = 0.42476573$

$l_b = 300.00$

$l_d = 706.2717$

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

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 257.6106$

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

$s = \max(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

End Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (b)

## Calculation No. 8

column C1, Floor 1

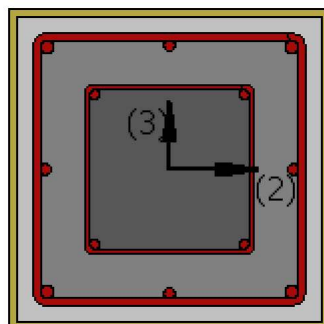
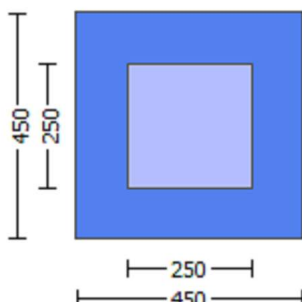
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\phi$ )

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjrs

#### Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

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

#####

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 2.0531359E-031$

EDGE -B-

Shear Force,  $V_b = -2.0531359E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{slt} = 0.00$

-Compression:  $Asl_c = 2676.637$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $Asl_{ten} = 1137.257$   
 -Compression:  $Asl_{com} = 1137.257$   
 -Middle:  $Asl_{mid} = 402.1239$

Calculation of Shear Capacity ratio ,  $Ve/V_r = 0.26068017$   
 Member Controlled by Flexure ( $Ve/V_r < 1$ )  
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $Ve = (M_{pr1} + M_{pr2})/l_n = 147952.607$   
 with

$M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 2.2193E+008$   
 $\mu_{u1+} = 2.2193E+008$ , 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  
 $\mu_{u1-} = 2.2193E+008$ , 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  
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 2.2193E+008$   
 $\mu_{u2+} = 2.2193E+008$ , 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  
 $\mu_{u2-} = 2.2193E+008$ , 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:  
 $\mu_u = 1.9632832E-005$   
 $\mu_u = 2.2193E+008$

with full section properties:

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.00124204$   
 $N = 7506.808$   
 $f_c = 33.00$   
 $\alpha_1 (5A.5, \text{TB DY}) = 0.002$   
 Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \alpha_1) = 0.01393923$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TB DY:  $\mu_u = 0.01393923$   
 $\mu_{ue} ((5.4c), \text{TB DY}) = \alpha_1 * \mu_{ue} / f_{ce} + \text{Min}(\mu_{ue}, \mu_{ue}) = 0.06811101$   
 where  $\mu_{ue} = \alpha_1 * \mu_{ue} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\mu_{ue} = 0.06628267$   
 $\alpha_1 = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
 From EC8 A4.4.3(6),  $\mu_{ue} = 2t_f/bw = 0.00451556$   
 $bw = 450.00$   
 effective stress from (A.35),  $f_{fe} = 881.8461$

$\mu_{ue} = 0.06628267$   
 $\alpha_1 = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
 From EC8 A4.4.3(6),  $\mu_{ue} = 2t_f/bw = 0.00451556$   
 $bw = 450.00$   
 effective stress from (A.35),  $f_{fe} = 881.8461$

$R = 40.00$   
 Effective FRP thickness,  $t_f = N L^* t \cos(b_1) = 1.016$   
 $f_u, f = 1055.00$   
 $E_f = 64828.00$

$u, f = 0.015$   
 $ase ((5.4d), TBDY) = (ase1 \cdot A_{ext} + ase2 \cdot A_{int}) / A_{sec} = 0.14546167$   
 $ase1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi2_1 = 608400.00$   
 $ase2 = \text{Max}(ase1, ase2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi2_2 = 234256.00$   
 $psh, \min \cdot F_{ywe} = \text{Min}(psh, x \cdot F_{ywe}, psh, y \cdot F_{ywe}) = 1.38262$   
 Expression ((5.4d), TBDY) for  $psh, \min \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh, x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / A_{sec} = 0.00116355$   
 $Ash1 = Astir_1 \cdot ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / A_{sec} = 0.00103427$   
 $Ash2 = Astir_2 \cdot ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

$psh, y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / A_{sec} = 0.00116355$   
 $Ash1 = Astir_1 \cdot ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / A_{sec} = 0.00103427$   
 $Ash2 = Astir_2 \cdot ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

$A_{sec} = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $fce = 33.00$   
 From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lo, \min = lb/ld = 0.33981258$   
 $su1 = 0.4 \cdot esu1_{\text{nominal}} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu1_{\text{nominal}} = 0.08$ ,  
 For calculation of  $esu1_{\text{nominal}}$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1 / 1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs1 = (fs, \text{jacket} \cdot A_{sl, \text{ten, jacket}} + fs, \text{core} \cdot A_{sl, \text{ten, core}}) / A_{sl, \text{ten}} = 399.8226$   
 with  $Es1 = (Es, \text{jacket} \cdot A_{sl, \text{ten, jacket}} + Es, \text{core} \cdot A_{sl, \text{ten, core}}) / A_{sl, \text{ten}} = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lo, \min = lb/lb, \min = 0.33981258$



$su_2 = 0.4 \cdot esu_{2\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2\_nominal} = 0.08$ ,  
 For calculation of  $esu_{2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 399.8226$   
 with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.00152175$   
 $sh_v = 0.0048696$   
 $ft_v = 507.2537$   
 $fy_v = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{u,min} = lb/ld = 0.33981258$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 422.7114$   
 with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.0752324$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.0752324$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.09371431$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.09371431$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.16791801$

$\mu_u = MR_c (4.14) = 2.2193E+008$

$u = su (4.1) = 1.9632832E-005$

-----  
 Calculation of ratio  $lb/ld$

-----  
 Lap Length:  $lb/ld = 0.33981258$

$lb = 300.00$

$ld = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} <= 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$

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

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

## Calculation of Mu1-

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

$$\mu = 1.9632832E-005$$

$$Mu = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu = \text{shear\_factor} * \text{Max}(\mu, \alpha) = 0.01393923$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01393923$$

$$\mu_e ((5.4c), TBDY) = \alpha * \mu_{sh,min} * f_{ywe} / f_{ce} + \text{Min}(\mu_x, \mu_y) = 0.06811101$$

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

$$\mu_x = 0.06628267$$

$$\alpha = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{sh,min} = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$\mu_y = 0.06628267$$

$$\alpha = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{sh,min} = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

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

$$\alpha_e ((5.4d), TBDY) = (\alpha_{e1} * A_{ext} + \alpha_{e2} * A_{int}) / A_{sec} = 0.14546167$$

$$\alpha_{e1} = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i,2,1} = 608400.00$$

$$\alpha_{e2} = \text{Max}(\alpha_{e1}, \alpha_{e2}) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i,2,2} = 234256.00$$

$$\mu_{sh,min} * f_{ywe} = \text{Min}(\mu_{sh,x} * f_{ywe}, \mu_{sh,y} * f_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $\mu_{sh,min} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\mu_{sh,x} * f_{ywe} = \mu_{sh1} * f_{ywe1} + \mu_{sh2} * f_{ywe2} = 1.38262$$

$$\mu_{sh1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$\mu_{sh2} (\text{internal}) = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h2 = 250.00$$

$$\begin{aligned} psh\_y * Fywe &= psh1 * Fywe1 + ps2 * Fywe2 = 1.38262 \\ ps1 \text{ (external)} &= (Ash1 * h1 / s1) / Asec = 0.00116355 \\ Ash1 &= Astir\_1 * ns\_1 = 157.0796 \\ \text{No stirups, } ns\_1 &= 2.00 \\ h1 &= 450.00 \\ ps2 \text{ (internal)} &= (Ash2 * h2 / s2) / Asec = 0.00103427 \\ Ash2 &= Astir\_2 * ns\_2 = 100.531 \\ \text{No stirups, } ns\_2 &= 2.00 \\ h2 &= 250.00 \end{aligned}$$

$$Asec = 202500.00$$

$$s1 = 300.00$$

$$s2 = 120.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

$$\text{From } ((5.A5), \text{ TBDY}), \text{ TBDY: } cc = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$y1 = 0.00152175$$

$$sh1 = 0.0048696$$

$$ft1 = 479.7871$$

$$fy1 = 399.8226$$

$$su1 = 0.0066488$$

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

$$lo/lou, \min = lb/ld = 0.33981258$$

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

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs\_jacket * Asl, \text{ten}, \text{jacket} + fs\_core * Asl, \text{ten}, \text{core}) / Asl, \text{ten} = 399.8226$$

$$\text{with } Es1 = (Es\_jacket * Asl, \text{ten}, \text{jacket} + Es\_core * Asl, \text{ten}, \text{core}) / Asl, \text{ten} = 200000.00$$

$$y2 = 0.00152175$$

$$sh2 = 0.0048696$$

$$ft2 = 479.7871$$

$$fy2 = 399.8226$$

$$su2 = 0.0066488$$

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

$$lo/lou, \min = lb/lb, \min = 0.33981258$$

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

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2, ft2, fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs\_jacket * Asl, \text{com}, \text{jacket} + fs\_core * Asl, \text{com}, \text{core}) / Asl, \text{com} = 399.8226$$

$$\text{with } Es2 = (Es\_jacket * Asl, \text{com}, \text{jacket} + Es\_core * Asl, \text{com}, \text{core}) / Asl, \text{com} = 200000.00$$

$$yv = 0.00152175$$

$$shv = 0.0048696$$

$$ftv = 507.2537$$

$$fyv = 422.7114$$

$$suv = 0.0066488$$

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

$$lo/lou, \min = lb/ld = 0.33981258$$

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

From table 5A.1, TBDY: esuv\_nominal = 0.08,

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

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

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

```

with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438

```

and confined core properties:

```

b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
c = confinement factor = 1.10542
1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353

```

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

```

su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008
u = su (4.1) = 1.9632832E-005

```

Calculation of ratio lb/l<sub>d</sub>

Lap Length: lb/l<sub>d</sub> = 0.33981258

lb = 300.00

ld = 882.8396

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

= 1

db = 16.66667

Mean strength value of all re-bars: fy = 655.558

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 2.86234

Atr = Min(Atr\_x,Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y loxal axis

s = Max(s\_external,s\_internal) = 300.00

n = 12.00

Calculation of Mu2+

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

u = 1.9632832E-005

Mu = 2.2193E+008

with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.00124204

N = 7506.808

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01393923

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

From (5.4b), TBDY: cu = 0.01393923

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+Min( fx, fy) = 0.06811101  
where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.06628267  
af = 0.54930041  
b = 450.00  
h = 450.00  
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556  
bw = 450.00  
effective stress from (A.35), ffe = 881.8461

fy = 0.06628267  
af = 0.54930041  
b = 450.00  
h = 450.00  
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556  
bw = 450.00  
effective stress from (A.35), ffe = 881.8461

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) = (ase1\*Aext+ase2\*Aint)/Asec = 0.14546167  
ase1 = 0.12623274  
bo\_1 = 390.00  
ho\_1 = 390.00  
bi2\_1 = 608400.00  
ase2 = Max(ase1,ase2) = 0.18853448  
bo\_2 = 242.00  
ho\_2 = 242.00  
bi2\_2 = 234256.00  
psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 1.38262  
Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00  
From ((5.A5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542  
y1 = 0.00152175  
sh1 = 0.0048696

```

ft1 = 479.7871
fy1 = 399.8226
su1 = 0.0066488
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258
    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, ASCE 41-17.
    with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 399.8226
    with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00152175
sh2 = 0.0048696
ft2 = 479.7871
fy2 = 399.8226
su2 = 0.0066488
    using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.33981258
    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, ASCE 41-17.
    with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226
    with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00152175
shv = 0.0048696
ftv = 507.2537
fyv = 422.7114
suv = 0.0066488
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258
    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, ASCE 41-17.
    with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
    c = confinement factor = 1.10542
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
    2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
    v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008

```

$$u = su(4.1) = 1.9632832E-005$$

Calculation of ratio lb/d

Lap Length: lb/d = 0.33981258

lb = 300.00

ld = 882.8396

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

= 1

db = 16.66667

Mean strength value of all re-bars: fy = 655.558

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 2.86234

Atr = Min(Atr\_x, Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y loxal axis

s = Max(s\_external, s\_internal) = 300.00

n = 12.00

Calculation of Mu2-

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

$$u = 1.9632832E-005$$

$$Mu = 2.2193E+008$$

with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.00124204

N = 7506.808

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu:  $cu^* = shear\_factor \cdot \max(cu, cc) = 0.01393923$

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

From (5.4b), TBDY:  $cu = 0.01393923$

we ((5.4c), TBDY) =  $ase \cdot sh_{min} \cdot fy_{we} / fce + \min(fx, fy) = 0.06811101$

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

fx = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00451556$

bw = 450.00

effective stress from (A.35),  $ffe = 881.8461$

fy = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00451556$

bw = 450.00

effective stress from (A.35),  $ffe = 881.8461$

R = 40.00

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

fu,f = 1055.00

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$ase((5.4d), TBDY) = (ase1 \cdot A_{ext} + ase2 \cdot A_{int}) / A_{sec} = 0.14546167$$

$$ase1 = 0.12623274$$

$$bo_1 = 390.00$$

$$ho_1 = 390.00$$

$$bi2_1 = 608400.00$$

$$ase2 = \text{Max}(ase1, ase2) = 0.18853448$$

$$bo_2 = 242.00$$

$$ho_2 = 242.00$$

$$bi2_2 = 234256.00$$

$$psh, \min \cdot F_{ywe} = \text{Min}(psh, x \cdot F_{ywe}, psh, y \cdot F_{ywe}) = 1.38262$$

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

$$psh, x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 1.38262$$

$$ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / A_{sec} = 0.00116355$$

$$Ash1 = Astir_1 \cdot ns_1 = 157.0796$$

$$\text{No stirrups, } ns_1 = 2.00$$

$$h1 = 450.00$$

$$ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / A_{sec} = 0.00103427$$

$$Ash2 = Astir_2 \cdot ns_2 = 100.531$$

$$\text{No stirrups, } ns_2 = 2.00$$

$$h2 = 250.00$$

$$psh, y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 1.38262$$

$$ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / A_{sec} = 0.00116355$$

$$Ash1 = Astir_1 \cdot ns_1 = 157.0796$$

$$\text{No stirrups, } ns_1 = 2.00$$

$$h1 = 450.00$$

$$ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / A_{sec} = 0.00103427$$

$$Ash2 = Astir_2 \cdot ns_2 = 100.531$$

$$\text{No stirrups, } ns_2 = 2.00$$

$$h2 = 250.00$$

$$A_{sec} = 202500.00$$

$$s1 = 300.00$$

$$s2 = 120.00$$

$$fy_{we1} = 694.45$$

$$fy_{we2} = 555.55$$

$$f_{ce} = 33.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$y1 = 0.00152175$$

$$sh1 = 0.0048696$$

$$ft1 = 479.7871$$

$$fy1 = 399.8226$$

$$su1 = 0.0066488$$

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

$$lo/lo_{min} = lb/ld = 0.33981258$$

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

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

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

$$y1, sh1, ft1, fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 \cdot (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs1 = (fs_{jacket} \cdot A_{sl,ten,jacket} + fs_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 399.8226$$

$$\text{with } Es1 = (Es_{jacket} \cdot A_{sl,ten,jacket} + Es_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 200000.00$$

$$y2 = 0.00152175$$

$$sh2 = 0.0048696$$

$$ft2 = 479.7871$$

$$fy2 = 399.8226$$

$$su2 = 0.0066488$$

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



$l_o/l_{o,min} = l_b/l_{b,min} = 0.33981258$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 399.8226$   
 with  $Es_2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$   
 $y_v = 0.00152175$   
 $sh_v = 0.0048696$   
 $ft_v = 507.2537$   
 $fy_v = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.33981258$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fs_v/1.2$ , 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, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 422.7114$   
 with  $Es_v = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.0752324$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.0752324$   
 $v = A_{sl,mid} / (b * d) * (fs_v / fc) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.09371431$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.09371431$   
 $v = A_{sl,mid} / (b * d) * (fs_v / fc) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

$su (4.9) = 0.16791801$

$\mu_u = MR_c (4.14) = 2.2193E+008$

$u = su (4.1) = 1.9632832E-005$

-----  
 Calculation of ratio  $l_b/l_d$   
 -----

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $fc^{0.5} <= 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = Min(A_{tr,x}, A_{tr,y}) = 257.6106$

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

$s = Max(s_{external}, s_{internal}) = 300.00$

$$n = 12.00$$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$

Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$V_{\text{ColO}} = 567563.724$

$k_{nl} = 1$  (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)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 1.4404090\text{E}-011$

$\nu_u = 2.0531359\text{E}-031$

$d = 0.8 * h = 360.00$

$N_u = 7506.808$

$A_g = 202500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 300.00$

$V_{s1}$  is multiplied by  $\text{Col1} = 0.66666667$

$s/d = 0.83333333$

$V_{s2} = 74466.637$  is calculated for core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 120.00$

$V_{s2}$  is multiplied by  $\text{Col2} = 1.00$

$s/d = 0.60$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 214457.247$

$f = 0.95$ , 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:  $\theta_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 407.00

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$

$b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$

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

$V_{\text{ColO}} = 567563.724$

$k_{nl} = 1$  (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)  
Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $Mu = 1.4404090E-011$   
 $Vu = 2.0531359E-031$   
 $d = 0.8 \cdot h = 360.00$   
 $Nu = 7506.808$   
 $Ag = 202500.00$   
From (11.5.4.8), ACI 318-14:  $Vs = Vs1 + Vs2 = 144280.365$   
where:  
 $Vs1 = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $Av = 157079.633$   
 $fy = 555.56$   
 $s = 300.00$   
 $Vs1$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $Vs2 = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $Av = 100530.965$   
 $fy = 444.44$   
 $s = 120.00$   
 $Vs2$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $Vf ((11-3)-(11.4), ACI 440) = 214457.247$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
where  $a$  is the angle of the crack direction (see KANEPE).  
This later relation, considered as a function  $Vf( , )$ , is implemented for every different fiber orientation  $ai$ ,  
as well as for 2 crack directions,  $= 45^\circ$  and  $= -45^\circ$  to take into consideration the cyclic seismic loading.  
orientation 1:  $1 = b1 + 90^\circ = 90.00$   
 $Vf = \text{Min}(|Vf(45, 1)|, |Vf(-45, a1)|)$ , with:  
total thickness per orientation,  $tf1 = NL \cdot t / NoDir = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 407.00  
 $ffe ((11-5), ACI 440) = 259.312$   
 $Ef = 64828.00$   
 $fe = 0.004$ , from (11.6a), ACI 440  
with  $fu = 0.01$   
From (11-11), ACI 440:  $Vs + Vf \leq 579413.096$   
 $bw = 450.00$

-----  
End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At local axis: 3  
-----

-----  
Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjrs

Constant Properties

-----  
Knowledge Factor,  $= 0.85$   
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $fc = fcm = 33.00$   
New material of Primary Member: Steel Strength,  $fs = fsm = 555.56$   
Concrete Elasticity,  $Ec = 26999.444$   
Steel Elasticity,  $Es = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $fc = fcm = 20.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
Concrete Elasticity,  $E_c = 21019.039$   
Steel Elasticity,  $E_s = 200000.00$   
#####  
Note: Especially for the calculation of moment strengths,  
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
Jacket  
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
Existing Column  
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$   
#####  
External Height,  $H = 450.00$   
External Width,  $W = 450.00$   
Internal Height,  $H = 250.00$   
Internal Width,  $W = 250.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.10542  
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $\epsilon_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i: 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = -2.7162834E-031$   
EDGE -B-  
Shear Force,  $V_b = 2.7162834E-031$   
BOTH EDGES  
Axial Force,  $F = -7506.808$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{slt} = 0.00$   
-Compression:  $A_{slc} = 2676.637$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten} = 1137.257$   
-Compression:  $A_{sl,com} = 1137.257$   
-Middle:  $A_{sl,mid} = 402.1239$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$   
with  
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.2193E+008$   
 $M_{u1+} = 2.2193E+008$ , 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  
 $M_{u1-} = 2.2193E+008$ , 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  
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.2193E+008$

Mu2+ = 2.2193E+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

Mu2- = 2.2193E+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 Mu1+

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

$$\kappa_u = 1.9632832E-005$$

$$M_u = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

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

$$\text{Final value of } \kappa_u: \kappa_u^* = \text{shear\_factor} * \text{Max}(\kappa_u, \kappa_o) = 0.01393923$$

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

$$\text{From (5.4b), TBDY: } \kappa_u = 0.01393923$$

$$\omega_e \text{ ((5.4c), TBDY)} = a_{se} * \frac{\min(f_{ywe}/f_{ce}, \min(f_x, f_y))}{f_{ce}} = 0.06811101$$

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

$$f_x = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$f_y = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$a_{se1} = 0.12623274$$

$$b_{o\_1} = 390.00$$

$$h_{o\_1} = 390.00$$

$$b_{i2\_1} = 608400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$$

$$b_{o\_2} = 242.00$$

$$h_{o\_2} = 242.00$$

$$b_{i2\_2} = 234256.00$$

$$p_{sh, \min} * F_{ywe} = \text{Min}(p_{sh, x} * F_{ywe}, p_{sh, y} * F_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $p_{sh, \min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh, x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 1.38262$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir\_1} * n_{s\_1} = 157.0796$$

$$\text{No stirrups, } n_{s\_1} = 2.00$$

$$h_1 = 450.00$$

$$ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$$

$$Ash2 = Astir\_2 \cdot ns\_2 = 100.531$$

$$\text{No stirups, } ns\_2 = 2.00$$

$$h2 = 250.00$$

$$psh\_y \cdot Fywe = psh1 \cdot Fywe1 + ps2 \cdot Fywe2 = 1.38262$$

$$ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / Asec = 0.00116355$$

$$Ash1 = Astir\_1 \cdot ns\_1 = 157.0796$$

$$\text{No stirups, } ns\_1 = 2.00$$

$$h1 = 450.00$$

$$ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$$

$$Ash2 = Astir\_2 \cdot ns\_2 = 100.531$$

$$\text{No stirups, } ns\_2 = 2.00$$

$$h2 = 250.00$$

$$Asec = 202500.00$$

$$s1 = 300.00$$

$$s2 = 120.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

$$\text{From } ((5.A.5), \text{ TBDY}), \text{ TBDY: } cc = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$y1 = 0.00152175$$

$$sh1 = 0.0048696$$

$$ft1 = 479.7871$$

$$fy1 = 399.8226$$

$$su1 = 0.0066488$$

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

$$lo/lou, \min = lb/ld = 0.33981258$$

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

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs\_jacket \cdot Asl, \text{ten}, \text{jacket} + fs\_core \cdot Asl, \text{ten}, \text{core}) / Asl, \text{ten} = 399.8226$$

$$\text{with } Es1 = (Es\_jacket \cdot Asl, \text{ten}, \text{jacket} + Es\_core \cdot Asl, \text{ten}, \text{core}) / Asl, \text{ten} = 200000.00$$

$$y2 = 0.00152175$$

$$sh2 = 0.0048696$$

$$ft2 = 479.7871$$

$$fy2 = 399.8226$$

$$su2 = 0.0066488$$

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

$$lo/lou, \min = lb/lb, \min = 0.33981258$$

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

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2, ft2, fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs\_jacket \cdot Asl, \text{com}, \text{jacket} + fs\_core \cdot Asl, \text{com}, \text{core}) / Asl, \text{com} = 399.8226$$

$$\text{with } Es2 = (Es\_jacket \cdot Asl, \text{com}, \text{jacket} + Es\_core \cdot Asl, \text{com}, \text{core}) / Asl, \text{com} = 200000.00$$

$$yv = 0.00152175$$

$$shv = 0.0048696$$

$$ftv = 507.2537$$

$$fyv = 422.7114$$

$$suv = 0.0066488$$

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

$$lo/lou, \min = lb/ld = 0.33981258$$

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

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, ASCE 41-17.

with  $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 422.7114$

with  $Esv = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$

$1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.0752324$

$2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.0752324$

$v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$fcc$  (5A.2, TBDY) = 36.47874

$cc$  (5A.5, TBDY) = 0.00305417

$c$  = confinement factor = 1.10542

$1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.09371431$

$2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.09371431$

$v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs_{y2}$  - LHS eq.(4.5) is satisfied

--->

$su$  (4.9) = 0.16791801

$Mu = MRc$  (4.14) = 2.2193E+008

$u = su$  (4.1) = 1.9632832E-005

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.33981258$

$lb = 300.00$

$ld = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$Ktr = 2.86234$

$Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$

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

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

Calculation of  $Mu1$ -

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

$u = 1.9632832E-005$

$Mu = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$fc = 33.00$

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

Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$

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

From (5.4b), TBDY:  $c_u = 0.01393923$

$w_e$  ((5.4c), TBDY) =  $a_{se} * \text{sh\_min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$

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

$f_x = 0.06628267$

$a_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$f_y = 0.06628267$

$a_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$R = 40.00$

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) =  $(a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.14546167$

$a_{se1} = 0.12623274$

$bo\_1 = 390.00$

$ho\_1 = 390.00$

$bi2\_1 = 608400.00$

$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$

$bo\_2 = 242.00$

$ho\_2 = 242.00$

$bi2\_2 = 234256.00$

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 1.38262$

Expression ((5.4d), TBDY) for  $p_{sh,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 1.38262$

$ps1$  (external) =  $(A_{sh1} * h_1/s_1)/A_{sec} = 0.00116355$

$A_{sh1} = A_{stir\_1} * ns\_1 = 157.0796$

No stirrups,  $ns\_1 = 2.00$

$h_1 = 450.00$

$ps2$  (internal) =  $(A_{sh2} * h_2/s_2)/A_{sec} = 0.00103427$

$A_{sh2} = A_{stir\_2} * ns\_2 = 100.531$

No stirrups,  $ns\_2 = 2.00$

$h_2 = 250.00$

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 1.38262$

$ps1$  (external) =  $(A_{sh1} * h_1/s_1)/A_{sec} = 0.00116355$

$A_{sh1} = A_{stir\_1} * ns\_1 = 157.0796$

No stirrups,  $ns\_1 = 2.00$

$h_1 = 450.00$

$ps2$  (internal) =  $(A_{sh2} * h_2/s_2)/A_{sec} = 0.00103427$

$A_{sh2} = A_{stir\_2} * ns\_2 = 100.531$

No stirrups,  $ns\_2 = 2.00$

$h_2 = 250.00$

$A_{sec} = 202500.00$

$s_1 = 300.00$

$s_2 = 120.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$



```

c = confinement factor = 1.10542
y1 = 0.00152175
sh1 = 0.0048696
ft1 = 479.7871
fy1 = 399.8226
su1 = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258
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, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 399.8226
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00152175
sh2 = 0.0048696
ft2 = 479.7871
fy2 = 399.8226
su2 = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.33981258
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, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00152175
shv = 0.0048696
ftv = 507.2537
fyv = 422.7114
suv = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258
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, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
c = confinement factor = 1.10542
1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied

```

```

--->
su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008
u = su (4.1) = 1.9632832E-005
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.33981258
lb = 300.00
ld = 882.8396
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.98765, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.86234
Atr = Min(Atrx,Atry) = 257.6106
where Atrx, Atry are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(sexternal,sinternal) = 300.00
n = 12.00
-----
-----
-----

Calculation of Mu2+
-----
-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.9632832E-005
Mu = 2.2193E+008
-----

with full section properties:
b = 450.00
d = 407.00
d' = 43.00
v = 0.00124204
N = 7506.808
fc = 33.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01393923
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01393923
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.06811101
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
-----
fx = 0.06628267
af = 0.54930041
b = 450.00
h = 450.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556
bw = 450.00
effective stress from (A.35), ff,e = 881.8461
-----
fy = 0.06628267
af = 0.54930041
b = 450.00
h = 450.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556
bw = 450.00
effective stress from (A.35), ff,e = 881.8461
-----

```

$R = 40.00$   
 Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $ase((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.14546167$   
 $ase1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi2_1 = 608400.00$   
 $ase2 = \max(ase1, ase2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi2_2 = 234256.00$   
 $psh_{,min} * F_{ywe} = \min(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 1.38262$   
 Expression ((5.4d), TBDY) for  $psh_{,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 1.38262$   
 $ps1 \text{ (external)} = (A_{sh1} * h1 / s1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir\_1} * ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (A_{sh2} * h2 / s2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir\_2} * ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

$psh_{,y} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 1.38262$   
 $ps1 \text{ (external)} = (A_{sh1} * h1 / s1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir\_1} * ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (A_{sh2} * h2 / s2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir\_2} * ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

$A_{sec} = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $fy_{we1} = 694.45$   
 $fy_{we2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$

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

$lo/lo_{u,min} = lb/ld = 0.33981258$

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

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, ASCE 41-17.

with  $fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 399.8226$

with  $Es1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.33981258$   
 $su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 399.8226$   
with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.00152175$   
 $sh_v = 0.0048696$   
 $ft_v = 507.2537$   
 $fy_v = 422.7114$   
 $suv = 0.0066488$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.33981258$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 422.7114$   
with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.0752324$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.0752324$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.09371431$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.09371431$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.03503353$

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

--->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$$

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$$

$$n = 12.00$$

Calculation of  $\mu_2$ -

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

$$\mu = 1.9632832\text{E-}005$$

$$\mu_2 = 2.2193\text{E+}008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_s) = 0.01393923$$

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

$$\text{From (5.4b), TBDY: } \mu_c = 0.01393923$$

$$\mu_s \text{ ((5.4c), TBDY) } = \alpha s_e * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

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

$$f_x = 0.06628267$$

$$\alpha f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$f_y = 0.06628267$$

$$\alpha f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(\theta_1) = 1.016$$

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

$$E_f = 64828.00$$

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

$$\alpha s_e \text{ ((5.4d), TBDY) } = (\alpha s_1 * A_{ext} + \alpha s_2 * A_{int}) / A_{sec} = 0.14546167$$

$$\alpha s_1 = 0.12623274$$

$$b_{o\_1} = 390.00$$

$$h_{o\_1} = 390.00$$

$$b_{i2\_1} = 608400.00$$

$$\alpha s_2 = \text{Max}(\alpha s_1, \alpha s_2) = 0.18853448$$

$$b_{o\_2} = 242.00$$

$$h_{o\_2} = 242.00$$

$$b_{i2\_2} = 234256.00$$

$$p_{sh, \text{min}} * f_{ywe} = \text{Min}(p_{sh, x} * f_{ywe}, p_{sh, y} * f_{ywe}) = 1.38262$$

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

$$p_{sh\_x} * f_{ywe} = p_{sh1} * f_{ywe1} + p_{s2} * f_{ywe2} = 1.38262$$

$$p_{s1} \text{ (external) } = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir\_1} * n_{s\_1} = 157.0796$$

$$\text{No stirrups, } n_{s\_1} = 2.00$$

$h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 \cdot ns\_2 = 100.531$   
 No stirups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$psh\_y \cdot Fywe = psh1 \cdot Fywe1 + ps2 \cdot Fywe2 = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 \cdot ns\_1 = 157.0796$   
 No stirups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 \cdot ns\_2 = 100.531$   
 No stirups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$Asec = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$

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

$lo/lou, min = lb/ld = 0.33981258$

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

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

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs,jacket \cdot Asl,ten,jacket + fs,core \cdot Asl,ten,core) / Asl,ten = 399.8226$

with  $Es1 = (Es,jacket \cdot Asl,ten,jacket + Es,core \cdot Asl,ten,core) / Asl,ten = 200000.00$

$y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$

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

$lo/lou, min = lb/lb, min = 0.33981258$

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

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs,jacket \cdot Asl,com,jacket + fs,core \cdot Asl,com,core) / Asl,com = 399.8226$

with  $Es2 = (Es,jacket \cdot Asl,com,jacket + Es,core \cdot Asl,com,core) / Asl,com = 200000.00$

$yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$

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

$lo/lou, min = lb/ld = 0.33981258$

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

From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,

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

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

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{sj\_jacket} \cdot A_{sl\_mid\_jacket} + f_{sj\_mid} \cdot A_{sl\_mid\_core}) / A_{sl\_mid} = 422.7114$

with  $E_{sv} = (E_{sj\_jacket} \cdot A_{sl\_mid\_jacket} + E_{sj\_mid} \cdot A_{sl\_mid\_core}) / A_{sl\_mid} = 200000.00$

$1 = A_{sl\_ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0752324$

$2 = A_{sl\_com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0752324$

$v = A_{sl\_mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$f_{cc}$  (5A.2, TBDY) = 36.47874

$cc$  (5A.5, TBDY) = 0.00305417

$c$  = confinement factor = 1.10542

$1 = A_{sl\_ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09371431$

$2 = A_{sl\_com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09371431$

$v = A_{sl\_mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su$  (4.9) = 0.16791801

$Mu = MR_c$  (4.14) = 2.2193E+008

$u = su$  (4.1) = 1.9632832E-005

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot Area\_jacket + f'_{c\_core} \cdot Area\_core) / Area\_section = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$

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

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$

Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$V_{Col0} = 567563.724$

$k_{nl} = 1$  (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)

Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot Area\_jacket + f'_{c\_core} \cdot Area\_core) / Area\_section = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu = 1.0463738E-012$   
 $\nu = 2.7162834E-031$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f ((11-3)-(11.4), ACI 440) = 214457.247$   
 $f = 0.95$ , 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:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{Col0}$   
 $V_{Col0} = 567563.724$   
 $knl = 1$  (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)  
 Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot Area\_jacket + f'_{c\_core} \cdot Area\_core) / Area\_section = 28.98765$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu = 1.0463738E-012$   
 $\nu = 2.7162834E-031$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:



$d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 Vs2 is multiplied by Col2 = 1.00  
 $s/d = 0.60$   
 $V_f((11-3)-(11.4), \text{ACI 440}) = 214457.247$   
 $f = 0.95$ , 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:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L * t / N_{\text{Dir}} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $b_w = 450.00$

-----  
 -----  
 End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
 At local axis: 2

-----  
 Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1  
 At local axis: 3  
 Integration Section: (b)  
 Section Type: rcjrs

#### Constant Properties

-----  
 Knowledge Factor,  $\phi = 0.85$   
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.  
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
 Concrete Elasticity,  $E_c = 21019.039$   
 Steel Elasticity,  $E_s = 200000.00$   
 External Height,  $H = 450.00$   
 External Width,  $W = 450.00$   
 Internal Height,  $H = 250.00$   
 Internal Width,  $W = 250.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Primary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_b = 300.00$   
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)

Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $e_{fu} = 0.01$   
Number of directions,  $NoDir = 1$   
Fiber orientations,  $bi = 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = 0.06012619$   
Shear Force,  $V_2 = 7697.601$   
Shear Force,  $V_3 = -1.7235006E-013$   
Axial Force,  $F = -7503.728$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
- Tension:  $As_t = 0.00$   
- Compression:  $As_c = 2676.637$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
- Tension:  $As_{ten} = 1137.257$   
- Compression:  $As_{com} = 1137.257$   
- Middle:  $As_{mid} = 402.1239$   
Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
- Tension:  $As_{ten,jacket} = 829.3805$   
- Compression:  $As_{com,jacket} = 829.3805$   
- Middle:  $As_{mid,jacket} = 402.1239$   
Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
- Tension:  $As_{ten,core} = 307.8761$   
- Compression:  $As_{com,core} = 307.8761$   
- Middle:  $As_{mid,core} = 0.00$   
Mean Diameter of Tension Reinforcement,  $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = u = 0.00055254$   
 $u = y + p = 0.00065005$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00065005$  ((4.29), Biskinis Phd))  
 $M_y = 1.7613E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 300.00  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.7095E+013$   
factor = 0.30  
 $A_g = 202500.00$   
Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.98765$   
 $N = 7503.728$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 9.0315E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 6.1806747E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 374.3546$   
 $d = 407.00$   
 $y = 0.25591435$   
 $A = 0.0147239$   
 $B = 0.00818869$   
with  $pt = 0.00430549$   
 $pc = 0.00620943$

$p_v = 0.0021956$   
 $N = 7503.728$   
 $b = 450.00$   
 $" = 0.10565111$   
 $y_{comp} = 2.2127278E-005$   
 with  $f_c^* (12.3, (ACI 440)) = 34.40847$   
 $f_c = 33.00$   
 $f_l = 0.82797802$   
 $b = 450.00$   
 $h = 450.00$   
 $A_g = 202500.00$   
 From (12.9), ACI 440:  $k_a = 0.54261599$   
 $g = p_t + p_c + p_v = 0.01461445$   
 $r_c = 40.00$   
 $A_e/A_c = 0.54261599$   
 Effective FRP thickness,  $t_f = N L^* t^* \cos(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.25471862$   
 $A = 0.01452515$   
 $B = 0.00807924$   
 with  $E_s = 200000.00$

#### Calculation of ratio $l_b/l_d$

Lap Length:  $l_d/l_{d,min} = 0.42476573$

$l_b = 300.00$

$l_d = 706.2717$

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

$= 1$

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$

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

$s = \max(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

#### - Calculation of $p$ -

From table 10-8:  $p = 0.00$

with:

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

shear control ratio  $V_y E / V_{col} E = 0.26068017$

$d = d_{external} = 407.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00430549$

jacket:  $s_1 = A_{v1} \cdot h_1 / (s_1 \cdot A_g) = 0.00116355$

$A_{v1} = 157.0796$ , is the total area of all stirrups parallel to loading (shear) direction

$h_1 = 450.00$

$s_1 = 300.00$

core:  $s_2 = A_{v2} \cdot h_2 / (s_2 \cdot A_g) = 0.00103427$

$A_{v2} = 100.531$ , is the total area of all stirrups parallel to loading (shear) direction

$h_2 = 250.00$

$s_2 = 120.00$

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.

For the normalisation  $f_s$  of jacket is used.

$$N_{UD} = 7503.728$$

$$A_g = 202500.00$$

$$f_{cE} = (f_{c\_jacket} \cdot Area\_jacket + f_{c\_core} \cdot Area\_core) / section\_area = 28.98765$$

$$f_{yE} = (f_{y\_ext\_Long\_Reinf} \cdot Area\_ext\_Long\_Reinf + f_{y\_int\_Long\_Reinf} \cdot Area\_int\_Long\_Reinf) / Area\_Tot\_Long\_Rein = 529.9972$$

$$f_{ytE} = (f_{y\_ext\_Trans\_Reinf} \cdot s_1 + f_{y\_int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 503.2682$$

$$\rho_l = Area\_Tot\_Long\_Rein / (b \cdot d) = 0.01461445$$

$$b = 450.00$$

$$d = 407.00$$

$$f_{cE} = 28.98765$$

End Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (b)

## Calculation No. 9

column C1, Floor 1

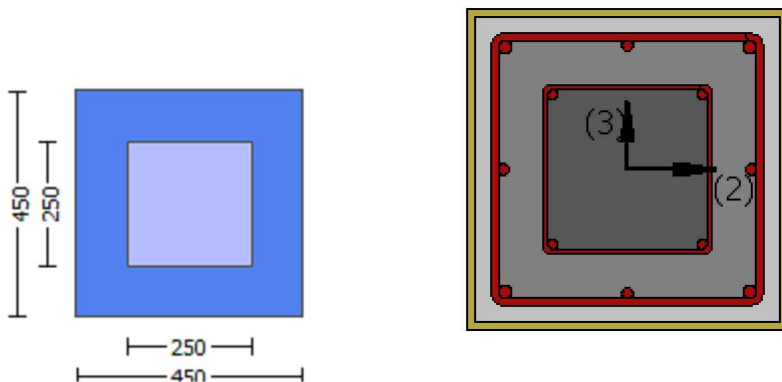
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$   
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.  
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
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, ASCE 41-17) because bending is considered as  
Deformation-Controlled Action (Table C7-1, ASCE 41-17).  
Jacket  
New material: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material: Steel Strength,  $f_s = f_{sm} = 555.56$   
Existing Column  
Existing material: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material: Steel Strength,  $f_s = f_{sm} = 444.44$   
#####  
External Height,  $H = 450.00$   
External Width,  $W = 450.00$   
Internal Height,  $H = 250.00$   
Internal Width,  $W = 250.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = l_b = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $\epsilon_{fu} = 0.01$   
Number of directions,  $N_{Dir} = 1$   
Fiber orientations,  $b_i: 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$

#### ----- Stepwise Properties -----

EDGE -A-  
Bending Moment,  $M_a = -3.5352E+007$   
Shear Force,  $V_a = -11781.223$   
EDGE -B-  
Bending Moment,  $M_b = 0.09202348$   
Shear Force,  $V_b = 11781.223$   
BOTH EDGES  
Axial Force,  $F = -7502.094$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 1137.257$   
-Compression:  $As_c = 1539.38$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{l,ten} = 1137.257$   
-Compression:  $As_{l,com} = 1137.257$   
-Middle:  $As_{l,mid} = 402.1239$

Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41-17: Final Shear Capacity  $V_R = V_n = 365324.544$

$V_n ((10.3), ASCE 41-17) = knl * V_{Col0} = 429793.581$

$V_{Col} = 429793.581$

$knl = 1.00$

$displacement\_ductility\_demand = 0.05733393$

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)

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 22.22222$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$M_u = 3.5352E+007$

$V_u = 11781.223$

$d = 0.8 * h = 360.00$

$N_u = 7502.094$

$A_g = 202500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 129852.496$

where:

$V_{s1} = 62831.853$  is calculated for jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 300.00$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$s/d = 0.83333333$

$V_{s2} = 67020.643$  is calculated for core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 120.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.60$

$V_f ((11-3)-(11.4), ACI 440) = 214457.247$

$f = 0.95$ , for fully-wrapped sections

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

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

where  $\theta$  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:  $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \alpha_1)|)$ , with:

total thickness per orientation,  $tf_1 = NL * t / NoDir = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 407.00

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 507312.442$

$bw = 450.00$

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

- Calculation of  $\Delta / y$  for END A -

for rotation axis 3 and integ. section (a)

From analysis, chord rotation  $\theta = 0.00037279$

$y = (M_y * L_s / 3) / E_{eff} = 0.006502 ((4.29), Biskinis Phd))$

$M_y = 1.7613E+008$

$L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 3000.708  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 2.7095E+013$   
 factor = 0.30  
 $A_g = 202500.00$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$   
 $N = 7502.094$   
 $E_c \cdot I_g = E_{c\_jacket} \cdot I_{g\_jacket} + E_{c\_core} \cdot I_{g\_core} = 9.0315E+013$

#### Calculation of Yielding Moment $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 6.1806717E-006$   
 with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b/I_d)^{2/3}) = 374.3546$   
 $d = 407.00$   
 $y = 0.25591399$   
 $A = 0.01472387$   
 $B = 0.00818866$   
 with  $pt = 0.00620943$   
 $pc = 0.00620943$   
 $pv = 0.0021956$   
 $N = 7502.094$   
 $b = 450.00$   
 $" = 0.10565111$   
 $y_{comp} = 2.2127287E-005$   
 with  $f_c^*$  (12.3, (ACI 440)) = 34.40847  
 $f_c = 33.00$   
 $f_l = 0.82797802$   
 $b = 450.00$   
 $h = 450.00$   
 $A_g = 202500.00$   
 From (12.9), ACI 440:  $k_a = 0.54261599$   
 $g = pt + pc + pv = 0.01461445$   
 $rc = 40.00$   
 $A_e/A_c = 0.54261599$   
 Effective FRP thickness,  $t_f = N_L \cdot t \cdot \cos(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.25471852$   
 $A = 0.01452517$   
 $B = 0.00807924$   
 with  $E_s = 200000.00$

#### Calculation of ratio $I_b/I_d$

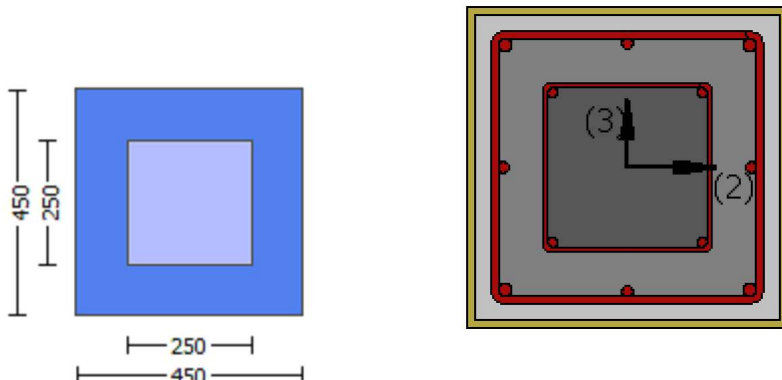
Lap Length:  $I_d/I_{d,min} = 0.42476573$   
 $I_b = 300.00$   
 $I_d = 706.2717$   
 Calculation of  $I$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 524.4464$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$

where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s\_external, s\_internal) = 300.00$   
 $n = 12.00$

End Of Calculation of Shear Capacity for element: column JC1 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 JC1 of floor 1  
At Shear local axis: 3  
(Bending local axis: 2)  
Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\phi = 0.85$   
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
Concrete Elasticity,  $E_c = 21019.039$   
Steel Elasticity,  $E_s = 200000.00$



```

#####
Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Jacket
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$ 
Existing Column
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$ 
#####
External Height,  $H = 450.00$ 
External Width,  $W = 450.00$ 
Internal Height,  $H = 250.00$ 
Internal Width,  $W = 250.00$ 
Cover Thickness,  $c = 25.00$ 
Mean Confinement Factor overall section = 1.10542
Element Length,  $L = 3000.00$ 
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length  $l_o = 300.00$ 
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $\epsilon_{fu} = 0.01$ 
Number of directions,  $N_{oDir} = 1$ 
Fiber orientations,  $b_i: 0.00^\circ$ 
Number of layers,  $N_L = 1$ 
Radius of rounding corners,  $R = 40.00$ 
-----

Stepwise Properties
-----
At local axis: 3
EDGE -A-
Shear Force,  $V_a = 2.0531359E-031$ 
EDGE -B-
Shear Force,  $V_b = -2.0531359E-031$ 
BOTH EDGES
Axial Force,  $F = -7506.808$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $A_{sl,t} = 0.00$ 
-Compression:  $A_{sl,c} = 2676.637$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension:  $A_{sl,ten} = 1137.257$ 
-Compression:  $A_{sl,com} = 1137.257$ 
-Middle:  $A_{sl,mid} = 402.1239$ 
-----
-----

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.26068017$ 
Member Controlled by Flexure ( $V_e/V_r < 1$ )
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$ 
with
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 2.2193E+008$ 
 $Mu_{1+} = 2.2193E+008$ , 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
 $Mu_{1-} = 2.2193E+008$ , 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
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 2.2193E+008$ 
 $Mu_{2+} = 2.2193E+008$ , 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
 $Mu_{2-} = 2.2193E+008$ , 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  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.9632832E-005$$

$$\mu = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu = \text{shear\_factor} * \text{Max}(\mu, \alpha) = 0.01393923$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01393923$$

$$\mu_{we} ((5.4c), TBDY) = \alpha * \mu_{sh,min} * f_{ywe} / f_{ce} + \text{Min}(\mu_x, \mu_y) = 0.06811101$$

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

$$\mu_x = 0.06628267$$

$$\alpha = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A4.4.3(6), } \mu_{sh,min} = 2t_f/bw = 0.00451556$$

$$bw = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$\mu_y = 0.06628267$$

$$\alpha = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A4.4.3(6), } \mu_{sh,min} = 2t_f/bw = 0.00451556$$

$$bw = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

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

$$\mu_{ase} ((5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$\alpha_{se1} = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i,2,1} = 608400.00$$

$$\alpha_{se2} = \text{Max}(\alpha_{se1}, \alpha_{se2}) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i,2,2} = 234256.00$$

$$\mu_{sh,min} * f_{ywe} = \text{Min}(\mu_{sh,x} * f_{ywe}, \mu_{sh,y} * f_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $\mu_{sh,min} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\mu_{sh,x} * f_{ywe} = \mu_{sh1} * f_{ywe1} + \mu_{sh2} * f_{ywe2} = 1.38262$$

$$\mu_{ps1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$\mu_{ps2} (\text{internal}) = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h2 = 250.00$$

$$\begin{aligned} psh\_y * Fywe &= psh1 * Fywe1 + ps2 * Fywe2 = 1.38262 \\ ps1 \text{ (external)} &= (Ash1 * h1 / s1) / Asec = 0.00116355 \\ Ash1 &= Astir\_1 * ns\_1 = 157.0796 \\ \text{No stirups, } ns\_1 &= 2.00 \\ h1 &= 450.00 \\ ps2 \text{ (internal)} &= (Ash2 * h2 / s2) / Asec = 0.00103427 \\ Ash2 &= Astir\_2 * ns\_2 = 100.531 \\ \text{No stirups, } ns\_2 &= 2.00 \\ h2 &= 250.00 \end{aligned}$$

$$Asec = 202500.00$$

$$s1 = 300.00$$

$$s2 = 120.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

$$\text{From } ((5.A.5), \text{ TBDY}), \text{ TBDY: } cc = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$y1 = 0.00152175$$

$$sh1 = 0.0048696$$

$$ft1 = 479.7871$$

$$fy1 = 399.8226$$

$$su1 = 0.0066488$$

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

$$lo/lou, \min = lb/ld = 0.33981258$$

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

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs\_jacket * Asl, \text{ten, jacket} + fs\_core * Asl, \text{ten, core}) / Asl, \text{ten} = 399.8226$$

$$\text{with } Es1 = (Es\_jacket * Asl, \text{ten, jacket} + Es\_core * Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$$

$$y2 = 0.00152175$$

$$sh2 = 0.0048696$$

$$ft2 = 479.7871$$

$$fy2 = 399.8226$$

$$su2 = 0.0066488$$

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

$$lo/lou, \min = lb/lb, \min = 0.33981258$$

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

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2, ft2, fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs\_jacket * Asl, \text{com, jacket} + fs\_core * Asl, \text{com, core}) / Asl, \text{com} = 399.8226$$

$$\text{with } Es2 = (Es\_jacket * Asl, \text{com, jacket} + Es\_core * Asl, \text{com, core}) / Asl, \text{com} = 200000.00$$

$$yv = 0.00152175$$

$$shv = 0.0048696$$

$$ftv = 507.2537$$

$$fyv = 422.7114$$

$$suv = 0.0066488$$

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

$$lo/lou, \min = lb/ld = 0.33981258$$

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

From table 5A.1, TBDY: esuv\_nominal = 0.08,

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

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

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

```

with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438

```

and confined core properties:

```

b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
c = confinement factor = 1.10542
1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353

```

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

```

su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008
u = su (4.1) = 1.9632832E-005

```

Calculation of ratio lb/l<sub>d</sub>

Lap Length: lb/l<sub>d</sub> = 0.33981258

lb = 300.00

ld = 882.8396

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

= 1

db = 16.66667

Mean strength value of all re-bars: fy = 655.558

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 2.86234

Atr = Min(Atr\_x,Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y loxal axis

s = Max(s\_external,s\_internal) = 300.00

n = 12.00

Calculation of Mu1-

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

u = 1.9632832E-005

Mu = 2.2193E+008

with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.00124204

N = 7506.808

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01393923

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

From (5.4b), TBDY: cu = 0.01393923

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+Min( fx, fy) = 0.06811101  
where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.06628267  
af = 0.54930041  
b = 450.00  
h = 450.00  
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556  
bw = 450.00  
effective stress from (A.35), ffe = 881.8461

fy = 0.06628267  
af = 0.54930041  
b = 450.00  
h = 450.00  
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556  
bw = 450.00  
effective stress from (A.35), ffe = 881.8461

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) = (ase1\*Aext+ase2\*Aint)/Asec = 0.14546167  
ase1 = 0.12623274  
bo\_1 = 390.00  
ho\_1 = 390.00  
bi2\_1 = 608400.00  
ase2 = Max(ase1,ase2) = 0.18853448  
bo\_2 = 242.00  
ho\_2 = 242.00  
bi2\_2 = 234256.00  
psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 1.38262  
Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00  
From ((5.A5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542  
y1 = 0.00152175  
sh1 = 0.0048696

```

ft1 = 479.7871
fy1 = 399.8226
su1 = 0.0066488
    using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.33981258
    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, ASCE 41-17.
    with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 399.8226
    with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00152175
sh2 = 0.0048696
ft2 = 479.7871
fy2 = 399.8226
su2 = 0.0066488
    using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.33981258
    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, ASCE 41-17.
    with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226
    with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00152175
shv = 0.0048696
ftv = 507.2537
fyv = 422.7114
suv = 0.0066488
    using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.33981258
    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, ASCE 41-17.
    with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
    c = confinement factor = 1.10542
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
    2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
    v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008

```

$$u = s_u(4.1) = 1.9632832E-005$$

Calculation of ratio  $l_b/d$

Lap Length:  $l_b/d = 0.33981258$

$l_b = 300.00$

$d = 882.8396$

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

$= 1$

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 257.6106$

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

$s = \max(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

Calculation of  $\mu_{2+}$

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

$$u = 1.9632832E-005$$

$$\mu = 2.2193E+008$$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$\phi_0$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} \cdot \max(\phi_u, \phi_c) = 0.01393923$

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

From (5.4b), TBDY:  $\phi_u = 0.01393923$

we ((5.4c), TBDY) =  $\alpha_{se} \cdot \phi_{u,min} \cdot f_{ywe} / f_{ce} + \min(\phi_{ux}, \phi_{uy}) = 0.06811101$

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

$\phi_{ux} = 0.06628267$

$\alpha_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A4.4.3(6),  $\phi_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$\phi_{uy} = 0.06628267$

$\alpha_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A4.4.3(6),  $\phi_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$   
 $u, f = 0.015$   
 $ase((5.4d), TBDY) = (ase1 \cdot A_{ext} + ase2 \cdot A_{int}) / A_{sec} = 0.14546167$   
 $ase1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi2_1 = 608400.00$   
 $ase2 = \text{Max}(ase1, ase2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi2_2 = 234256.00$   
 $psh, \min \cdot F_{ywe} = \text{Min}(psh, x \cdot F_{ywe}, psh, y \cdot F_{ywe}) = 1.38262$   
 Expression ((5.4d), TBDY) for  $psh, \min \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh, x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / A_{sec} = 0.00116355$   
 $Ash1 = Astir_1 \cdot ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / A_{sec} = 0.00103427$   
 $Ash2 = Astir_2 \cdot ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

$psh, y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / A_{sec} = 0.00116355$   
 $Ash1 = Astir_1 \cdot ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / A_{sec} = 0.00103427$   
 $Ash2 = Astir_2 \cdot ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

$A_{sec} = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $f_{ce} = 33.00$   
 From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/ld = 0.33981258$   
 $su1 = 0.4 \cdot esu1_{\text{nominal}}((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu1_{\text{nominal}} = 0.08$ ,  
 For calculation of  $esu1_{\text{nominal}}$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1 / 1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs1 = (fs, \text{jacket} \cdot A_{sl, \text{ten, jacket}} + fs, \text{core} \cdot A_{sl, \text{ten, core}}) / A_{sl, \text{ten}} = 399.8226$   
 with  $Es1 = (Es, \text{jacket} \cdot A_{sl, \text{ten, jacket}} + Es, \text{core} \cdot A_{sl, \text{ten, core}}) / A_{sl, \text{ten}} = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$



$l_o/l_{o,min} = l_b/l_{b,min} = 0.33981258$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 399.8226$   
 with  $Es_2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$   
 $y_v = 0.00152175$   
 $sh_v = 0.0048696$   
 $ft_v = 507.2537$   
 $fy_v = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.33981258$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsv = fs_v/1.2$ , 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, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 422.7114$   
 with  $Es_v = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.0752324$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.0752324$   
 $v = A_{sl,mid} / (b * d) * (fs_v / fc) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.09371431$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.09371431$   
 $v = A_{sl,mid} / (b * d) * (fs_v / fc) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

$su (4.9) = 0.16791801$

$Mu = MRc (4.14) = 2.2193E+008$

$u = su (4.1) = 1.9632832E-005$

-----  
 Calculation of ratio  $l_b/l_d$   
 -----

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} <= 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = Min(A_{tr,x}, A_{tr,y}) = 257.6106$

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

$s = Max(s_{external}, s_{internal}) = 300.00$

$$n = 12.00$$

Calculation of Mu2-

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

$$u = 1.9632832E-005$$

$$Mu = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_o) = 0.01393923$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01393923$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

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

$$f_x = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$f_y = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$a_{se1} = 0.12623274$$

$$b_{o\_1} = 390.00$$

$$h_{o\_1} = 390.00$$

$$b_{i2\_1} = 608400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$$

$$b_{o\_2} = 242.00$$

$$h_{o\_2} = 242.00$$

$$b_{i2\_2} = 234256.00$$

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $p_{sh,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 1.38262$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir\_1} * n_{s\_1} = 157.0796$$

$$\text{No stirrups, } n_{s\_1} = 2.00$$

$$h_1 = 450.00$$

$$p_{s2} \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir\_2} * n_{s\_2} = 100.531$$

No stirups, ns\_2 = 2.00  
h2 = 250.00

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirups, ns\_2 = 2.00  
h2 = 250.00

Asec = 202500.00

s1 = 300.00

s2 = 120.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417

c = confinement factor = 1.10542

y1 = 0.00152175

sh1 = 0.0048696

ft1 = 479.7871

fy1 = 399.8226

su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258

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, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175

sh2 = 0.0048696

ft2 = 479.7871

fy2 = 399.8226

su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.33981258

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, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 399.8226

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00152175

shv = 0.0048696

ftv = 507.2537

fyv = 422.7114

suv = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

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

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $f_{sv} = (f_{sjacket} \cdot A_{sl,mid,jacket} + f_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 422.7114$   
 with  $E_{sv} = (E_{sjacket} \cdot A_{sl,mid,jacket} + E_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0752324$   
 $2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0752324$   
 $v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.02812438$   
 and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} \text{ (5A.2, TBDY)} = 36.47874$   
 $c_c \text{ (5A.5, TBDY)} = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09371431$   
 $2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09371431$   
 $v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su \text{ (4.9)} = 0.16791801$   
 $\mu_u = M_{Rc} \text{ (4.14)} = 2.2193E+008$   
 $u = su \text{ (4.1)} = 1.9632832E-005$   
 -----  
 Calculation of ratio  $lb/ld$   
 -----  
 Lap Length:  $lb/ld = 0.33981258$   
 $lb = 300.00$   
 $ld = 882.8396$   
 Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 655.558$   
 Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}, A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$   
 -----  
 -----  
 -----  
 Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$   
 -----  
 Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$   
 $V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} \cdot V_{Col0}$   
 $V_{Col0} = 567563.724$   
 $k_{nl} = 1$  (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)  
 Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.4404090E-011$   
 $V_u = 2.0531359E-031$   
 $d = 0.8 \cdot h = 360.00$

$Nu = 7506.808$   
 $Ag = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $Vs = Vs1 + Vs2 = 144280.365$   
 where:  
 $Vs1 = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $Av = 157079.633$   
 $fy = 555.56$   
 $s = 300.00$   
 $Vs1$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $Vs2 = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $Av = 100530.965$   
 $fy = 444.44$   
 $s = 120.00$   
 $Vs2$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $Vf ((11-3)-(11.4), ACI 440) = 214457.247$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $Vf( , )$ , 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:  $a_1 = b_1 + 90^\circ = 90.00$   
 $Vf = \text{Min}(|Vf(45, 1)|, |Vf(-45, a_1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL * t / NoDir = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 407.00  
 $ffe ((11-5), ACI 440) = 259.312$   
 $Ef = 64828.00$   
 $fe = 0.004$ , from (11.6a), ACI 440  
 with  $fu = 0.01$   
 From (11-11), ACI 440:  $Vs + Vf \leq 579413.096$   
 $bw = 450.00$

Calculation of Shear Strength at edge 2,  $Vr2 = 567563.724$   
 $Vr2 = VCol ((10.3), ASCE 41-17) = knl * VCol0$   
 $VCol0 = 567563.724$   
 $knl = 1$  (zero step-static loading)

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

$= 1$  (normal-weight concrete)  
 Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $Mu = 1.4404090E-011$   
 $Vu = 2.0531359E-031$   
 $d = 0.8 * h = 360.00$   
 $Nu = 7506.808$   
 $Ag = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $Vs = Vs1 + Vs2 = 144280.365$   
 where:  
 $Vs1 = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $Av = 157079.633$   
 $fy = 555.56$   
 $s = 300.00$   
 $Vs1$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $Vs2 = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $Av = 100530.965$   
 $fy = 444.44$

$s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f((11-3)-(11.4), ACI 440) = 214457.247$   
 $f = 0.95$ , 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:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
total thickness per orientation,  $t_{f1} = NL * t / NoDir = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe}((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
with  $f_u = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $b_w = 450.00$

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\phi = 0.85$   
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
Concrete Elasticity,  $E_c = 21019.039$   
Steel Elasticity,  $E_s = 200000.00$   
#####  
Note: Especially for the calculation of moment strengths,  
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
Jacket  
New material: Steel Strength,  $f_s = 1.25 * f_{sm} = 694.45$   
Existing Column  
Existing material: Steel Strength,  $f_s = 1.25 * f_{sm} = 555.55$   
#####  
External Height,  $H = 450.00$   
External Width,  $W = 450.00$   
Internal Height,  $H = 250.00$   
Internal Width,  $W = 250.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.10542  
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

Number of directions,  $NoDir = 1$

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,  $V_a = -2.7162834E-031$

EDGE -B-

Shear Force,  $V_b = 2.7162834E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

-Middle:  $As_{mid} = 402.1239$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$  with

$M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 2.2193E+008$

$\mu_{u1+} = 2.2193E+008$ , 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

$\mu_{u1-} = 2.2193E+008$ , 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

$M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 2.2193E+008$

$\mu_{u2+} = 2.2193E+008$ , 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

$\mu_{u2-} = 2.2193E+008$ , 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:

$\phi_u = 1.9632832E-005$

$\mu_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

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

Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$

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

From (5.4b), TBDY:  $c_u = 0.01393923$

$w_e$  ((5.4c), TBDY) =  $a_{se} * \text{sh\_min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$

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

$f_x = 0.06628267$

$a_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$f_y = 0.06628267$

$a_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$R = 40.00$

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) =  $(a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$

$a_{se1} = 0.12623274$

$bo\_1 = 390.00$

$ho\_1 = 390.00$

$bi2\_1 = 608400.00$

$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$

$bo\_2 = 242.00$

$ho\_2 = 242.00$

$bi2\_2 = 234256.00$

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 1.38262$

Expression ((5.4d), TBDY) for  $p_{sh,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 1.38262$

$ps1$  (external) =  $(A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$

$A_{sh1} = A_{stir\_1} * ns\_1 = 157.0796$

No stirrups,  $ns\_1 = 2.00$

$h_1 = 450.00$

$ps2$  (internal) =  $(A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$

$A_{sh2} = A_{stir\_2} * ns\_2 = 100.531$

No stirrups,  $ns\_2 = 2.00$

$h_2 = 250.00$

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 1.38262$

$ps1$  (external) =  $(A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$

$A_{sh1} = A_{stir\_1} * ns\_1 = 157.0796$

No stirrups,  $ns\_1 = 2.00$

$h_1 = 450.00$

$ps2$  (internal) =  $(A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$

$A_{sh2} = A_{stir\_2} * ns\_2 = 100.531$

No stirrups,  $ns\_2 = 2.00$

$h_2 = 250.00$

$A_{sec} = 202500.00$

$s_1 = 300.00$

$s_2 = 120.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$



```

c = confinement factor = 1.10542
y1 = 0.00152175
sh1 = 0.0048696
ft1 = 479.7871
fy1 = 399.8226
su1 = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258
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, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 399.8226
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00152175
sh2 = 0.0048696
ft2 = 479.7871
fy2 = 399.8226
su2 = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.33981258
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, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00152175
shv = 0.0048696
ftv = 507.2537
fyv = 422.7114
suv = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258
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, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
c = confinement factor = 1.10542
1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied

```

```

--->
su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008
u = su (4.1) = 1.9632832E-005
-----

Calculation of ratio lb/ld
-----

Lap Length: lb/ld = 0.33981258
lb = 300.00
ld = 882.8396
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.98765, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.86234
Atr = Min(Atrx,Atry) = 257.6106
where Atrx, Atry are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(sexternal,sinternal) = 300.00
n = 12.00
-----

Calculation of Mu1-
-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.9632832E-005
Mu = 2.2193E+008
-----

with full section properties:
b = 450.00
d = 407.00
d' = 43.00
v = 0.00124204
N = 7506.808
fc = 33.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01393923
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01393923
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.06811101
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
-----

fx = 0.06628267
af = 0.54930041
b = 450.00
h = 450.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556
bw = 450.00
effective stress from (A.35), ff,e = 881.8461
-----

fy = 0.06628267
af = 0.54930041
b = 450.00
h = 450.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556
bw = 450.00
effective stress from (A.35), ff,e = 881.8461
-----

```

$R = 40.00$   
 Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $f_u, f = 1055.00$   
 $E_f = 64828.00$   
 $u, f = 0.015$   
 $ase((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.14546167$   
 $ase1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi2_1 = 608400.00$   
 $ase2 = \max(ase1, ase2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi2_2 = 234256.00$   
 $psh, min * F_{ywe} = \min(psh, x * F_{ywe}, psh, y * F_{ywe}) = 1.38262$   
 Expression ((5.4d), TBDY) for  $psh, min * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh, x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 1.38262$   
 $ps1 \text{ (external)} = (A_{sh1} * h1 / s1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir, 1} * ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (A_{sh2} * h2 / s2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir, 2} * ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

$psh, y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 1.38262$   
 $ps1 \text{ (external)} = (A_{sh1} * h1 / s1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir, 1} * ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (A_{sh2} * h2 / s2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir, 2} * ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

$A_{sec} = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$

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

$lo/lo_{u,min} = lb/ld = 0.33981258$   
 $su1 = 0.4 * esu1_{nominal}((5.5), TBDY) = 0.032$

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, ASCE 41-17.

with  $fs1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 399.8226$

with  $Es1 = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.33981258$   
 $su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 399.8226$   
with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.00152175$   
 $sh_v = 0.0048696$   
 $ft_v = 507.2537$   
 $fy_v = 422.7114$   
 $suv = 0.0066488$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.33981258$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 422.7114$   
with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.0752324$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.0752324$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.09371431$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.09371431$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.03503353$

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

--->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$$

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$$

$$n = 12.00$$

Calculation of  $\mu_{2+}$

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

$$\mu = 1.9632832E-005$$

$$\mu_{2+} = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_{cu} = \text{shear\_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.01393923$$

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

$$\text{From (5.4b), TBDY: } \mu_{cu} = 0.01393923$$

$$\mu_{we} \text{ ((5.4c), TBDY) } = \alpha_{se} * \mu_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.06811101$$

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

$$\mu_{fx} = 0.06628267$$

$$\alpha_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{pf} = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$\mu_{fy} = 0.06628267$$

$$\alpha_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{pf} = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(\theta_1) = 1.016$$

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

$$E_f = 64828.00$$

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

$$\alpha_{se} \text{ ((5.4d), TBDY) } = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$\alpha_{se1} = 0.12623274$$

$$b_{o\_1} = 390.00$$

$$h_{o\_1} = 390.00$$

$$b_{i2\_1} = 608400.00$$

$$\alpha_{se2} = \text{Max}(\alpha_{se1}, \alpha_{se2}) = 0.18853448$$

$$b_{o\_2} = 242.00$$

$$h_{o\_2} = 242.00$$

$$b_{i2\_2} = 234256.00$$

$$\mu_{psh, \min} * f_{ywe} = \text{Min}(\mu_{psh, x} * f_{ywe}, \mu_{psh, y} * f_{ywe}) = 1.38262$$

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

$$\mu_{psh, x} * f_{ywe} = \mu_{psh1} * f_{ywe1} + \mu_{psh2} * f_{ywe2} = 1.38262$$

$$\mu_{ps1} \text{ (external) } = (\alpha_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$\alpha_{sh1} = A_{stir\_1} * n_{s\_1} = 157.0796$$

$$\text{No stirrups, } n_{s\_1} = 2.00$$

$h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 \cdot ns\_2 = 100.531$   
 No stirups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$psh\_y \cdot Fywe = psh1 \cdot Fywe1 + ps2 \cdot Fywe2 = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 \cdot ns\_1 = 157.0796$   
 No stirups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 \cdot ns\_2 = 100.531$   
 No stirups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$Asec = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$

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

$lo/lou, min = lb/ld = 0.33981258$

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

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

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs\_jacket \cdot Asl, ten, jacket + fs\_core \cdot Asl, ten, core) / Asl, ten = 399.8226$

with  $Es1 = (Es\_jacket \cdot Asl, ten, jacket + Es\_core \cdot Asl, ten, core) / Asl, ten = 200000.00$

$y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$

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

$lo/lou, min = lb/lb, min = 0.33981258$

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

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs\_jacket \cdot Asl, com, jacket + fs\_core \cdot Asl, com, core) / Asl, com = 399.8226$

with  $Es2 = (Es\_jacket \cdot Asl, com, jacket + Es\_core \cdot Asl, com, core) / Asl, com = 200000.00$

$yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$

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

$lo/lou, min = lb/ld = 0.33981258$

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

From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,

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

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 422.7114$

with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0752324$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0752324$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$f_{cc}$  (5A.2, TBDY) = 36.47874

$cc$  (5A.5, TBDY) = 0.00305417

$c$  = confinement factor = 1.10542

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09371431$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09371431$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su$  (4.9) = 0.16791801

$\mu_u = MR_c$  (4.14) = 2.2193E+008

$u = su$  (4.1) = 1.9632832E-005

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot A_{jacket} + f'_{c,core} \cdot A_{core}) / A_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

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

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

Calculation of  $\mu_{u2}$

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

$u = 1.9632832E-005$

$\mu_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

```

co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01393923
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01393923
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.06811101
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
-----
fx = 0.06628267
af = 0.54930041
b = 450.00
h = 450.00
From EC8 A4.4.3(6), pf = 2tf/bw = 0.00451556
bw = 450.00
effective stress from (A.35), ffe = 881.8461
-----
fy = 0.06628267
af = 0.54930041
b = 450.00
h = 450.00
From EC8 A4.4.3(6), pf = 2tf/bw = 0.00451556
bw = 450.00
effective stress from (A.35), ffe = 881.8461
-----
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) = (ase1*Aext+ase2*Aint)/Asec = 0.14546167
ase1 = 0.12623274
bo_1 = 390.00
ho_1 = 390.00
bi2_1 = 608400.00
ase2 = Max(ase1,ase2) = 0.18853448
bo_2 = 242.00
ho_2 = 242.00
bi2_2 = 234256.00
psh,min*Fywe = Min(psh,x*Fywe , psh,y*Fywe) = 1.38262
Expression ((5.4d), TBDY) for psh,min*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without
earthquake detailing (90° closed stirrups)
-----
psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 1.38262
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00116355
Ash1 = Astir_1*ns_1 = 157.0796
No stirups, ns_1 = 2.00
h1 = 450.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00103427
Ash2 = Astir_2*ns_2 = 100.531
No stirups, ns_2 = 2.00
h2 = 250.00
-----
psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 1.38262
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00116355
Ash1 = Astir_1*ns_1 = 157.0796
No stirups, ns_1 = 2.00
h1 = 450.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00103427
Ash2 = Astir_2*ns_2 = 100.531
No stirups, ns_2 = 2.00
h2 = 250.00
-----
Asec = 202500.00
s1 = 300.00
s2 = 120.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

```



From ((5.A.5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/ld = 0.33981258$   
 $su1 = 0.4*esu1\_nominal ((5.5), TBDY) = 0.032$   
 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, ASCE 41-17.  
 with  $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 399.8226$   
 with  $Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/lb,min = 0.33981258$   
 $su2 = 0.4*esu2\_nominal ((5.5), TBDY) = 0.032$   
 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, ASCE 41-17.  
 with  $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226$   
 with  $Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/ld = 0.33981258$   
 $suv = 0.4*esuv\_nominal ((5.5), TBDY) = 0.032$   
 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, ASCE 41-17.  
 with  $fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114$   
 with  $Es_v = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438$   
 and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

---

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

---->

$$s_u(4.9) = 0.16791801$$

$$M_u = M_{Rc}(4.14) = 2.2193E+008$$

$$u = s_u(4.1) = 1.9632832E-005$$

Calculation of ratio  $l_b/l_d$

$$\text{Lap Length: } l_b/l_d = 0.33981258$$

$$l_b = 300.00$$

$$l_d = 882.8396$$

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

$$d_b = 16.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 655.558$$

$$\text{Mean concrete strength: } f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 28.98765, \text{ but } f'_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$$

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

$$s = \text{Max}(s_{external}, s_{internal}) = 300.00$$

$$n = 12.00$$

$$\text{Calculation of Shear Strength } V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$$

$$\text{Calculation of Shear Strength at edge 1, } V_{r1} = 567563.724$$

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

$$V_{Col0} = 567563.724$$

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

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

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

$$\text{Mean concrete strength: } f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 28.98765, \text{ but } f'_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$M_u = 1.0463738E-012$$

$$V_u = 2.7162834E-031$$

$$d = 0.8 \cdot h = 360.00$$

$$N_u = 7506.808$$

$$A_g = 202500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 144280.365$$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 300.00$$

$$V_{s1} \text{ is multiplied by } Col1 = 0.66666667$$

$$s/d = 0.83333333$$

$V_{s2} = 74466.637$  is calculated for core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 444.44$$

$$s = 120.00$$

$$V_{s2} \text{ is multiplied by } Col2 = 1.00$$

$$s/d = 0.60$$

$$V_f((11-3)-(11.4), \text{ACI 440}) = 214457.247$$

$f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin \theta + \cos \theta$  is replaced with  $(\cot \theta + \csc \theta) \sin \alpha$  which is more a generalised expression,  
 where  $\theta$  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:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL * t / NoDir = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe}((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$   
 $V_{r2} = V_{Col}((10.3), ASCE 41-17) = knl * V_{ColO}$   
 $V_{ColO} = 567563.724$   
 $knl = 1$  (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).

$\gamma_c = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_{c\_jacket} * Area\_jacket + f'_{c\_core} * Area\_core) / Area\_section = 28.98765$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.0463738E-012$   
 $\nu_u = 2.7162834E-031$   
 $d = 0.8 * h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f((11-3)-(11.4), ACI 440) = 214457.247$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin \theta + \cos \theta$  is replaced with  $(\cot \theta + \csc \theta) \sin \alpha$  which is more a generalised expression,  
 where  $\theta$  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:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL * t / NoDir = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe}((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$

bw = 450.00

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1  
At local axis: 2

Integration Section: (a)  
Section Type: rcjrs

#### Constant Properties

Knowledge Factor,  $\gamma = 0.85$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -5.3402437E-010$

Shear Force,  $V_2 = -11781.223$

Shear Force,  $V_3 = 2.6378276E-013$

Axial Force,  $F = -7502.094$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 1137.257$

-Compression:  $As_c = 1539.38$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

-Middle:  $Asl_{mid} = 402.1239$   
 Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $Asl_{ten,jacket} = 829.3805$   
 -Compression:  $Asl_{com,jacket} = 829.3805$   
 -Middle:  $Asl_{mid,jacket} = 402.1239$   
 Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $Asl_{ten,core} = 307.8761$   
 -Compression:  $Asl_{com,core} = 307.8761$   
 -Middle:  $Asl_{mid,core} = 0.00$   
 Mean Diameter of Tension Reinforcement,  $DbL = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = \frac{1}{2} u = 0.03558642$   
 $u = y + p = 0.04186638$

- Calculation of  $y$  -

$y = (My * Ls / 3) / Eleff = 0.00325023$  ((4.29), Biskinis Phd))  
 $My = 1.7613E+008$   
 $Ls = M/V$  (with  $Ls > 0.1 * L$  and  $Ls < 2 * L$ ) = 1500.00  
 From table 10.5, ASCE 41\_17:  $Eleff = factor * Ec * Ig = 2.7095E+013$   
 $factor = 0.30$   
 $Ag = 202500.00$   
 Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 28.98765$   
 $N = 7502.094$   
 $Ec * Ig = Ec_{jacket} * Ig_{jacket} + Ec_{core} * Ig_{core} = 9.0315E+013$

Calculation of Yielding Moment  $My$

Calculation of  $y$  and  $My$  according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 6.1806717E-006$   
 with ((10.1), ASCE 41-17)  $fy = \text{Min}(fy, 1.25 * fy * (lb/d)^{2/3}) = 374.3546$   
 $d = 407.00$   
 $y = 0.25591399$   
 $A = 0.01472387$   
 $B = 0.00818866$   
 with  $pt = 0.00430549$   
 $pc = 0.00620943$   
 $p_v = 0.0021956$   
 $N = 7502.094$   
 $b = 450.00$   
 $" = 0.10565111$   
 $y_{comp} = 2.2127287E-005$   
 with  $fc' (12.3, (ACI 440)) = 34.40847$   
 $fc = 33.00$   
 $fl = 0.82797802$   
 $b = 450.00$   
 $h = 450.00$   
 $Ag = 202500.00$   
 From (12.9), ACI 440:  $ka = 0.54261599$   
 $g = pt + pc + p_v = 0.01461445$   
 $rc = 40.00$   
 $Ae/Ac = 0.54261599$   
 Effective FRP thickness,  $tf = NL * t * \text{Cos}(b1) = 1.016$   
 effective strain from (12.5) and (12.12),  $efe = 0.004$   
 $fu = 0.01$   
 $Ef = 64828.00$   
 $Ec = 26999.444$   
 $y = 0.25471852$   
 $A = 0.01452517$

B = 0.00807924  
with Es = 200000.00

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_d/l_{d,min} = 0.42476573$

$l_b = 300.00$

$l_d = 706.2717$

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

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 257.6106$

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

$s = \max(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

- Calculation of  $p$  -

From table 10-8:  $p = 0.03861614$

with:

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

shear control ratio  $V_y E / V_{col} E = 0.26068017$

$d = d_{external} = 407.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00430549$

jacket:  $s_1 = A_{v1} \cdot h_1 / (s_1 \cdot A_g) = 0.00116355$

$A_{v1} = 157.0796$ , is the total area of all stirrups parallel to loading (shear) direction

$h_1 = 450.00$

$s_1 = 300.00$

core:  $s_2 = A_{v2} \cdot h_2 / (s_2 \cdot A_g) = 0.00103427$

$A_{v2} = 100.531$ , is the total area of all stirrups parallel to loading (shear) direction

$h_2 = 250.00$

$s_2 = 120.00$

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.

For the normalisation  $f_s$  of jacket is used.

$N_{UD} = 7502.094$

$A_g = 202500.00$

$f'_{cE} = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / section\_area = 28.98765$

$f_{yIE} = (f_{y,ext\_Long\_Reinf} \cdot Area_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} \cdot Area_{int\_Long\_Reinf}) / Area_{Tot\_Long\_Rein} = 529.9972$

$f_{ytE} = (f_{y,ext\_Trans\_Reinf} \cdot s_1 + f_{y,int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 503.2682$

$p_l = Area_{Tot\_Long\_Rein} / (b \cdot d) = 0.01461445$

$b = 450.00$

$d = 407.00$

$f'_{cE} = 28.98765$

End Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (a)

## Calculation No. 11

column C1, Floor 1

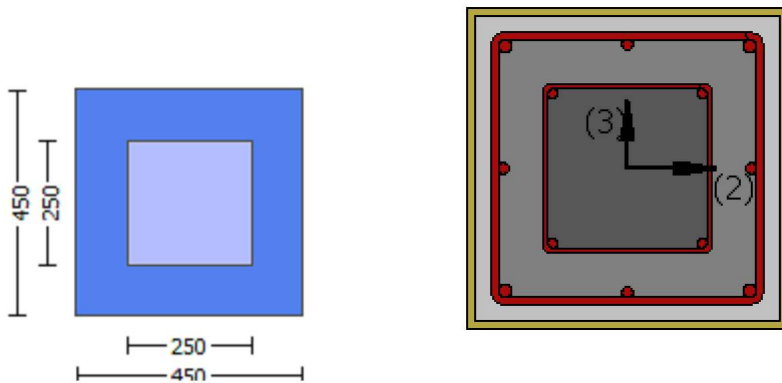
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

New material: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material: Steel Strength,  $f_s = f_{sm} = 555.56$

Existing Column

Existing material: Concrete Strength,  $f_c = f_{cm} = 20.00$   
 Existing material: Steel Strength,  $f_s = f_{sm} = 444.44$   
 #####  
 External Height,  $H = 450.00$   
 External Width,  $W = 450.00$   
 Internal Height,  $H = 250.00$   
 Internal Width,  $W = 250.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Primary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_o = l_b = 300.00$   
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $e_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i: 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

EDGE -A-  
 Bending Moment,  $M_a = -5.3402437E-010$   
 Shear Force,  $V_a = 2.6378276E-013$   
 EDGE -B-  
 Bending Moment,  $M_b = -2.5732098E-010$   
 Shear Force,  $V_b = -2.6378276E-013$   
 BOTH EDGES  
 Axial Force,  $F = -7502.094$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{slt} = 1137.257$   
   -Compression:  $A_{slc} = 1539.38$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{sl,ten} = 1137.257$   
   -Compression:  $A_{sl,com} = 1137.257$   
   -Middle:  $A_{sl,mid} = 402.1239$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = V_n = 447100.239$   
 $V_n ((10.3), ASCE 41-17) = knl * V_{CoI0} = 526000.281$   
 $V_{CoI} = 526000.281$   
 $knl = 1.00$   
 $displacement\_ductility\_demand = 0.00$

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

$= 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_c_{jacket} * Area_{jacket} + f'_c_{core} * Area_{core}) / Area_{section} = 22.22222$ , but  $f'_c^{0.5} < =$   
 8.3 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $M_u = 5.3402437E-010$   
 $V_u = 2.6378276E-013$   
 $d = 0.8 * h = 360.00$   
 $N_u = 7502.094$



$A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 129852.496$   
 where:  
 $V_{s1} = 62831.853$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 67020.643$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 400.00$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f ((11-3)-(11.4), ACI 440) = 214457.247$   
 $f = 0.95$ , 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,  $a = 45^\circ$  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,  $tf_1 = NL \cdot t / NoDir = 1.016$   
 $df_v = d$  (figure 11.2, ACI 440) = 407.00  
 $ff_e ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 507312.442$   
 $bw = 450.00$

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  $\theta = 7.9205223E-023$   
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00325023$  ((4.29), Biskinis Phd))  
 $M_y = 1.7613E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 1500.00  
 From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 2.7095E+013$   
 factor = 0.30  
 $A_g = 202500.00$   
 Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot \text{Area}_{jacket} + f'_{c\_core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 28.98765$   
 $N = 7502.094$   
 $E_c \cdot I_g = E_{c\_jacket} \cdot I_{g\_jacket} + E_{c\_core} \cdot I_{g\_core} = 9.0315E+013$

Calculation of Yielding Moment  $M_y$

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

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 6.1806717E-006$   
 with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 374.3546$   
 $d = 407.00$   
 $y = 0.25591399$   
 $A = 0.01472387$   
 $B = 0.00818866$   
 with  $pt = 0.00620943$

```

pc = 0.00620943
pv = 0.0021956
N = 7502.094
b = 450.00
" = 0.10565111
y_comp = 2.2127287E-005
with  $f_c^*$  (12.3, (ACI 440)) = 34.40847
fc = 33.00
fl = 0.82797802
b = 450.00
h = 450.00
Ag = 202500.00
From (12.9), ACI 440:  $k_a = 0.54261599$ 
 $g = p_t + p_c + p_v = 0.01461445$ 
rc = 40.00
Ae/Ac = 0.54261599
Effective FRP thickness,  $t_f = N L^* t \cos(b_1) = 1.016$ 
effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$ 
fu = 0.01
Ef = 64828.00
Ec = 26999.444
y = 0.25471852
A = 0.01452517
B = 0.00807924
with Es = 200000.00

```

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_d/l_{d,min} = 0.42476573$

$l_b = 300.00$

$l_d = 706.2717$

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

= 1

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$

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

$s = \max(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

End Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (a)

## Calculation No. 12

column C1, Floor 1

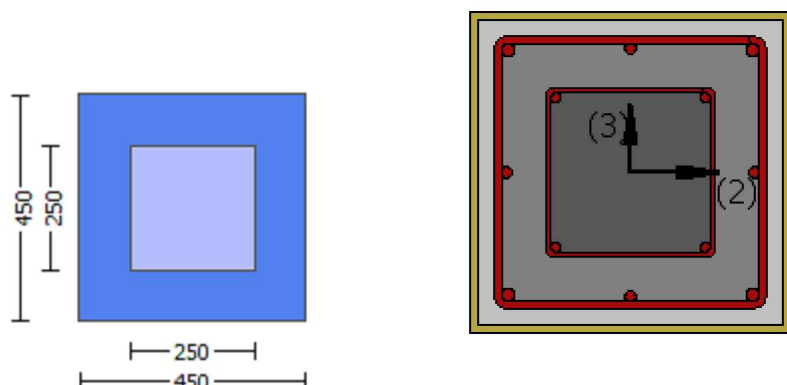
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

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

#####

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 2.0531359E-031$

EDGE -B-

Shear Force,  $V_b = -2.0531359E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

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

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$  with

$M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 2.2193E+008$

$\mu_{u1+} = 2.2193E+008$ , 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

$\mu_{u1-} = 2.2193E+008$ , 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

$M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 2.2193E+008$

$\mu_{u2+} = 2.2193E+008$ , 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

$\mu_{u2-} = 2.2193E+008$ , 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:

$\phi_u = 1.9632832E-005$

$\mu_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

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

Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$

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

From (5.4b), TBDY:  $c_u = 0.01393923$

$w_e$  ((5.4c), TBDY) =  $a_{se} * \text{sh\_min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$

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

$f_x = 0.06628267$

$a_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$f_y = 0.06628267$

$a_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$R = 40.00$

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) =  $(a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.14546167$

$a_{se1} = 0.12623274$

$bo\_1 = 390.00$

$ho\_1 = 390.00$

$bi2\_1 = 608400.00$

$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$

$bo\_2 = 242.00$

$ho\_2 = 242.00$

$bi2\_2 = 234256.00$

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 1.38262$

Expression ((5.4d), TBDY) for  $p_{sh,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 1.38262$

$ps1$  (external) =  $(A_{sh1} * h_1/s_1)/A_{sec} = 0.00116355$

$A_{sh1} = A_{stir\_1} * ns\_1 = 157.0796$

No stirrups,  $ns\_1 = 2.00$

$h_1 = 450.00$

$ps2$  (internal) =  $(A_{sh2} * h_2/s_2)/A_{sec} = 0.00103427$

$A_{sh2} = A_{stir\_2} * ns\_2 = 100.531$

No stirrups,  $ns\_2 = 2.00$

$h_2 = 250.00$

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 1.38262$

$ps1$  (external) =  $(A_{sh1} * h_1/s_1)/A_{sec} = 0.00116355$

$A_{sh1} = A_{stir\_1} * ns\_1 = 157.0796$

No stirrups,  $ns\_1 = 2.00$

$h_1 = 450.00$

$ps2$  (internal) =  $(A_{sh2} * h_2/s_2)/A_{sec} = 0.00103427$

$A_{sh2} = A_{stir\_2} * ns\_2 = 100.531$

No stirrups,  $ns\_2 = 2.00$

$h_2 = 250.00$

$A_{sec} = 202500.00$

$s_1 = 300.00$

$s_2 = 120.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$

```

c = confinement factor = 1.10542
y1 = 0.00152175
sh1 = 0.0048696
ft1 = 479.7871
fy1 = 399.8226
su1 = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258
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, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 399.8226
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00152175
sh2 = 0.0048696
ft2 = 479.7871
fy2 = 399.8226
su2 = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.33981258
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, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00152175
shv = 0.0048696
ftv = 507.2537
fyv = 422.7114
suv = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258
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, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
c = confinement factor = 1.10542
1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied

```

```

--->
su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008
u = su (4.1) = 1.9632832E-005
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.33981258
lb = 300.00
ld = 882.8396
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.98765, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.86234
Atr = Min(Atrx,Atry) = 257.6106
where Atrx, Atry are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(sexternal,sinternal) = 300.00
n = 12.00
-----
-----
-----

Calculation of Mu1-
-----
-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.9632832E-005
Mu = 2.2193E+008
-----

with full section properties:
b = 450.00
d = 407.00
d' = 43.00
v = 0.00124204
N = 7506.808
fc = 33.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01393923
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01393923
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.06811101
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
-----
fx = 0.06628267
af = 0.54930041
b = 450.00
h = 450.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556
bw = 450.00
effective stress from (A.35), ff,e = 881.8461
-----
fy = 0.06628267
af = 0.54930041
b = 450.00
h = 450.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556
bw = 450.00
effective stress from (A.35), ff,e = 881.8461
-----

```

$R = 40.00$   
 Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $ase((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.14546167$   
 $ase1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi2_1 = 608400.00$   
 $ase2 = \max(ase1, ase2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi2_2 = 234256.00$   
 $psh_{,min} * F_{ywe} = \min(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 1.38262$   
 Expression ((5.4d), TBDY) for  $psh_{,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 * h1 / s1) / A_{sec} = 0.00116355$   
 $Ash1 = Astir_1 * ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 * h2 / s2) / A_{sec} = 0.00103427$   
 $Ash2 = Astir_2 * ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

$psh_{,y} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 * h1 / s1) / A_{sec} = 0.00116355$   
 $Ash1 = Astir_1 * ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 * h2 / s2) / A_{sec} = 0.00103427$   
 $Ash2 = Astir_2 * ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

$A_{sec} = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lo_{u,min} = lb/ld = 0.33981258$   
 $su1 = 0.4 * esu1_{nominal}((5.5), TBDY) = 0.032$   
 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, ASCE 41-17.  
 with  $fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 399.8226$   
 with  $Es1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$



using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.33981258$   
 $su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 399.8226$   
with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.00152175$   
 $sh_v = 0.0048696$   
 $ft_v = 507.2537$   
 $fy_v = 422.7114$   
 $suv = 0.0066488$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.33981258$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 422.7114$   
with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.0752324$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.0752324$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.02812438$   
and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.09371431$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.09371431$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.03503353$   
Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)  
--->  
 $v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied  
--->  
 $su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

#### Calculation of ratio $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$   
 $l_b = 300.00$   
 $l_d = 882.8396$   
Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
= 1  
 $db = 16.66667$   
Mean strength value of all re-bars:  $fy = 655.558$   
Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} < =$   
8.3 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$

$$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$$

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$$

$$n = 12.00$$

Calculation of  $\mu_{2+}$

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

$$\mu = 1.9632832\text{E-}005$$

$$\mu_{\text{u}} = 2.2193\text{E+}008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_{\text{u}}: \mu_{\text{u}}^* = \text{shear\_factor} * \text{Max}(\mu_{\text{u}}, \mu_{\text{c}}) = 0.01393923$$

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

$$\text{From (5.4b), TBDY: } \mu_{\text{u}} = 0.01393923$$

$$\mu_{\text{u}} \text{ ((5.4c), TBDY) } = \alpha_{\text{se}} * \mu_{\text{sh,min}} * f_{y\text{we}} / f_{\text{ce}} + \text{Min}(\mu_{\text{fx}}, \mu_{\text{fy}}) = 0.06811101$$

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

$$\mu_{\text{fx}} = 0.06628267$$

$$\alpha_{\text{f}} = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{\text{pf}} = 2t_{\text{f}}/b_{\text{w}} = 0.00451556$$

$$b_{\text{w}} = 450.00$$

$$\text{effective stress from (A.35), } f_{\text{fe}} = 881.8461$$

$$\mu_{\text{fy}} = 0.06628267$$

$$\alpha_{\text{f}} = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{\text{pf}} = 2t_{\text{f}}/b_{\text{w}} = 0.00451556$$

$$b_{\text{w}} = 450.00$$

$$\text{effective stress from (A.35), } f_{\text{fe}} = 881.8461$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_{\text{f}} = N L * t * \text{Cos}(\theta_1) = 1.016$$

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

$$E_{\text{f}} = 64828.00$$

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

$$\alpha_{\text{se}} \text{ ((5.4d), TBDY) } = (\alpha_{\text{se1}} * A_{\text{ext}} + \alpha_{\text{se2}} * A_{\text{int}}) / A_{\text{sec}} = 0.14546167$$

$$\alpha_{\text{se1}} = 0.12623274$$

$$b_{\text{o}_1} = 390.00$$

$$h_{\text{o}_1} = 390.00$$

$$b_{\text{i}_2_1} = 608400.00$$

$$\alpha_{\text{se2}} = \text{Max}(\alpha_{\text{se1}}, \alpha_{\text{se2}}) = 0.18853448$$

$$b_{\text{o}_2} = 242.00$$

$$h_{\text{o}_2} = 242.00$$

$$b_{\text{i}_2_2} = 234256.00$$

$$\mu_{\text{psh,min}} * f_{y\text{we}} = \text{Min}(\mu_{\text{psh,x}} * f_{y\text{we}}, \mu_{\text{psh,y}} * f_{y\text{we}}) = 1.38262$$

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

$$\mu_{\text{psh,x}} * f_{y\text{we}} = \mu_{\text{psh1}} * f_{y\text{we1}} + \mu_{\text{ps2}} * f_{y\text{we2}} = 1.38262$$

$$\mu_{\text{ps1}} \text{ (external) } = (A_{\text{sh1}} * h_1 / s_1) / A_{\text{sec}} = 0.00116355$$

$$A_{\text{sh1}} = A_{\text{stir}_1} * n_{\text{s}_1} = 157.0796$$

$$\text{No stirrups, } n_{\text{s}_1} = 2.00$$

$h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 \cdot ns\_2 = 100.531$   
 No stirups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$psh\_y \cdot Fywe = psh1 \cdot Fywe1 + ps2 \cdot Fywe2 = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 \cdot ns\_1 = 157.0796$   
 No stirups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 \cdot ns\_2 = 100.531$   
 No stirups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$Asec = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$

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

$lo/lou,min = lb/ld = 0.33981258$

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

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

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1 / 1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs,jacket \cdot Asl,ten,jacket + fs,core \cdot Asl,ten,core) / Asl,ten = 399.8226$

with  $Es1 = (Es,jacket \cdot Asl,ten,jacket + Es,core \cdot Asl,ten,core) / Asl,ten = 200000.00$

$y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$

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

$lo/lou,min = lb/lb,min = 0.33981258$

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

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2 / 1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs,jacket \cdot Asl,com,jacket + fs,core \cdot Asl,com,core) / Asl,com = 399.8226$

with  $Es2 = (Es,jacket \cdot Asl,com,jacket + Es,core \cdot Asl,com,core) / Asl,com = 200000.00$

$yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$

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

$lo/lou,min = lb/ld = 0.33981258$

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

From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,

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

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 422.7114$

with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 200000.00$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0752324$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0752324$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$f_{cc}$  (5A.2, TBDY) = 36.47874

$cc$  (5A.5, TBDY) = 0.00305417

$c$  = confinement factor = 1.10542

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.09371431$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09371431$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su$  (4.9) = 0.16791801

$Mu = MR_c$  (4.14) = 2.2193E+008

$u = su$  (4.1) = 1.9632832E-005

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core})/Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

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

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

Calculation of  $Mu_2$ -

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

$u = 1.9632832E-005$

$Mu = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

```

co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01393923
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01393923
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.06811101
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
-----
fx = 0.06628267
af = 0.54930041
b = 450.00
h = 450.00
From EC8 A4.4.3(6), pf = 2tf/bw = 0.00451556
bw = 450.00
effective stress from (A.35), ffe = 881.8461
-----
fy = 0.06628267
af = 0.54930041
b = 450.00
h = 450.00
From EC8 A4.4.3(6), pf = 2tf/bw = 0.00451556
bw = 450.00
effective stress from (A.35), ffe = 881.8461
-----
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) = (ase1*Aext+ase2*Aint)/Asec = 0.14546167
ase1 = 0.12623274
bo_1 = 390.00
ho_1 = 390.00
bi2_1 = 608400.00
ase2 = Max(ase1,ase2) = 0.18853448
bo_2 = 242.00
ho_2 = 242.00
bi2_2 = 234256.00
psh,min*Fywe = Min(psh,x*Fywe , psh,y*Fywe) = 1.38262
Expression ((5.4d), TBDY) for psh,min*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without
earthquake detailing (90° closed stirrups)
-----
psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 1.38262
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00116355
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 450.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00103427
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 250.00
-----
psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 1.38262
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00116355
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 450.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00103427
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 250.00
-----
Asec = 202500.00
s1 = 300.00
s2 = 120.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

```

From ((5.A.5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/ld = 0.33981258$   
 $su1 = 0.4*esu1\_nominal ((5.5), TBDY) = 0.032$   
 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, ASCE 41-17.  
 with  $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 399.8226$   
 with  $Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/lb,min = 0.33981258$   
 $su2 = 0.4*esu2\_nominal ((5.5), TBDY) = 0.032$   
 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, ASCE 41-17.  
 with  $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226$   
 with  $Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/ld = 0.33981258$   
 $suv = 0.4*esuv\_nominal ((5.5), TBDY) = 0.032$   
 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, ASCE 41-17.  
 with  $fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114$   
 with  $Es_v = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438$   
 and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

---

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

--->

$$su(4.9) = 0.16791801$$

$$Mu = MRc(4.14) = 2.2193E+008$$

$$u = su(4.1) = 1.9632832E-005$$

Calculation of ratio  $l_b/l_d$

$$\text{Lap Length: } l_b/l_d = 0.33981258$$

$$l_b = 300.00$$

$$l_d = 882.8396$$

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

$$db = 16.66667$$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $fc' = (fc'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + fc'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$$

$$n = 12.00$$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$

Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$$V_{Col0} = 567563.724$$

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

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

= 1 (normal-weight concrete)

Mean concrete strength:  $fc' = (fc'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + fc'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$Mu = 1.4404090E-011$$

$$Vu = 2.0531359E-031$$

$$d = 0.8 \cdot h = 360.00$$

$$Nu = 7506.808$$

$$Ag = 202500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 144280.365$$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 300.00$$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$$s/d = 0.83333333$$

$V_{s2} = 74466.637$  is calculated for core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 444.44$$

$$s = 120.00$$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$$s/d = 0.60$$

$$V_f((11-3)-(11.4), \text{ACI } 440) = 214457.247$$

$f = 0.95$ , 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,  $tf1 = NL \cdot t / NoDir = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe}((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $bw = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$   
 $V_{r2} = V_{Col}((10.3), ASCE 41-17) = knl \cdot V_{ColO}$   
 $V_{ColO} = 567563.724$   
 $knl = 1$  (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).

$\gamma_c = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot Area\_jacket + f'_{c\_core} \cdot Area\_core) / Area\_section = 28.98765$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.4404090E-011$   
 $\nu_u = 2.0531359E-031$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f((11-3)-(11.4), ACI 440) = 214457.247$   
 $f = 0.95$ , 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,  $tf1 = NL \cdot t / NoDir = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe}((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$



bw = 450.00

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjrs

#### Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

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

#####

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

Number of directions,  $NoDir = 1$

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,  $V_a = -2.7162834E-031$

EDGE -B-

Shear Force,  $V_b = 2.7162834E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{ten} = 1137.257$

-Compression:  $As_{com} = 1137.257$

-Middle:  $As_{mid} = 402.1239$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.2193E+008$

$Mu_{1+} = 2.2193E+008$ , 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

$Mu_{1-} = 2.2193E+008$ , 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.2193E+008$

$Mu_{2+} = 2.2193E+008$ , 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

$Mu_{2-} = 2.2193E+008$ , 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:

$\phi_u = 1.9632832E-005$

$M_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$\alpha_1(5A.5, \text{TB DY}) = 0.002$

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01393923$

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

From (5.4b), TB DY:  $\phi_u = 0.01393923$

$\phi_{ue}((5.4c), \text{TB DY}) = \alpha_1 * \phi_{u,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.06811101$

where  $\phi_{fx} = \alpha_1 * \phi_{pf} * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_{fx} = 0.06628267$

$\alpha_1 = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $\phi_{pf} = 2t_f/b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$\phi_{fy} = 0.06628267$

$\alpha_1 = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $\phi_{pf} = 2t_f/b_w = 0.00451556$

bw = 450.00  
effective stress from (A.35),  $f_{f,e} = 881.8461$

R = 40.00  
Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $ase((5.4d), TBDY) = (ase_1 \cdot A_{ext} + ase_2 \cdot A_{int}) / A_{sec} = 0.14546167$   
 $ase_1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi2_1 = 608400.00$   
 $ase_2 = \max(ase_1, ase_2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi2_2 = 234256.00$

$psh_{min} \cdot F_{ywe} = \min(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 1.38262$

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

$psh_x \cdot F_{ywe} = psh_1 \cdot F_{ywe1} + ps_2 \cdot F_{ywe2} = 1.38262$   
 $ps_1 \text{ (external)} = (Ash_1 \cdot h_1 / s_1) / A_{sec} = 0.00116355$   
 $Ash_1 = Astir_1 \cdot ns_1 = 157.0796$   
No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2 \text{ (internal)} = (Ash_2 \cdot h_2 / s_2) / A_{sec} = 0.00103427$   
 $Ash_2 = Astir_2 \cdot ns_2 = 100.531$   
No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

$psh_y \cdot F_{ywe} = psh_1 \cdot F_{ywe1} + ps_2 \cdot F_{ywe2} = 1.38262$   
 $ps_1 \text{ (external)} = (Ash_1 \cdot h_1 / s_1) / A_{sec} = 0.00116355$   
 $Ash_1 = Astir_1 \cdot ns_1 = 157.0796$   
No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2 \text{ (internal)} = (Ash_2 \cdot h_2 / s_2) / A_{sec} = 0.00103427$   
 $Ash_2 = Astir_2 \cdot ns_2 = 100.531$   
No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

$A_{sec} = 202500.00$   
 $s_1 = 300.00$   
 $s_2 = 120.00$   
 $fy_{we1} = 694.45$   
 $fy_{we2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$

$c = \text{confinement factor} = 1.10542$

$y_1 = 0.00152175$   
 $sh_1 = 0.0048696$   
 $ft_1 = 479.7871$   
 $fy_1 = 399.8226$   
 $su_1 = 0.0066488$

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

$lo/lo_{u,min} = lb/ld = 0.33981258$

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

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  $fs_1 = fs_1 / 1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_1 = (fs_{jacket} \cdot A_{sl,ten,jacket} + fs_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 399.8226$

with  $Es_1 = (Es_{jacket} \cdot A_{sl,ten,jacket} + Es_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.00152175$   
 $sh_2 = 0.0048696$

```

ft2 = 479.7871
fy2 = 399.8226
su2 = 0.0066488
    using (30) in Biskinis/Fardis (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 = 0.33981258
    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, ASCE 41-17.
    with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226
    with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
    yv = 0.00152175
    shv = 0.0048696
ftv = 507.2537
fyv = 422.7114
suv = 0.0066488
    using (30) in Biskinis/Fardis (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 = 0.33981258
    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, ASCE 41-17.
    with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
    2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
    v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
c = confinement factor = 1.10542
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
    2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
    v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

```

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

```

---->
v < vs,y2 - LHS eq.(4.5) is satisfied
---->
su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008
u = su (4.1) = 1.9632832E-005

```

#### Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.33981258
lb = 300.00
lb = 882.8396
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.98765, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80

```

$e = 1.00$   
 $cb = 25.00$   
 $Ktr = 2.86234$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$   
 $n = 12.00$

Calculation of  $\mu_1$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:  
 $\mu = 1.9632832E-005$   
 $\mu = 2.2193E+008$

with full section properties:

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.00124204$   
 $N = 7506.808$   
 $f_c = 33.00$   
 $\alpha (5A.5, \text{TB DY}) = 0.002$   
 Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu, \alpha) = 0.01393923$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TB DY:  $\mu = 0.01393923$   
 $\mu_e ((5.4c), \text{TB DY}) = \alpha * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$   
 where  $f = \alpha * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06628267$   
 $\alpha_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$   
 $b_w = 450.00$   
 effective stress from (A.35),  $f_{fe} = 881.8461$

$f_y = 0.06628267$   
 $\alpha_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$   
 $b_w = 450.00$   
 effective stress from (A.35),  $f_{fe} = 881.8461$

$R = 40.00$   
 Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{f,f} = 0.015$   
 $\alpha_{se} ((5.4d), \text{TB DY}) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.14546167$   
 $\alpha_{se1} = 0.12623274$   
 $b_{o\_1} = 390.00$   
 $h_{o\_1} = 390.00$   
 $b_{i2\_1} = 608400.00$   
 $\alpha_{se2} = \text{Max}(\alpha_{se1}, \alpha_{se2}) = 0.18853448$   
 $b_{o\_2} = 242.00$   
 $h_{o\_2} = 242.00$   
 $b_{i2\_2} = 234256.00$

$p_{sh, \text{min}} * F_{ywe} = \text{Min}(p_{sh, x} * F_{ywe}, p_{sh, y} * F_{ywe}) = 1.38262$   
 Expression ((5.4d), TB DY) for  $p_{sh, \text{min}} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh, x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 1.38262$

$ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 \cdot ns\_1 = 157.0796$   
 $No \text{ stirups, } ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 \cdot ns\_2 = 100.531$   
 $No \text{ stirups, } ns\_2 = 2.00$   
 $h2 = 250.00$

$psh\_y \cdot Fywe = psh1 \cdot Fywe1 + ps2 \cdot Fywe2 = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 \cdot ns\_1 = 157.0796$   
 $No \text{ stirups, } ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 \cdot ns\_2 = 100.531$   
 $No \text{ stirups, } ns\_2 = 2.00$   
 $h2 = 250.00$

$Asec = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $fce = 33.00$

$From ((5A5), TBDY), TBDY: cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$

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

$lo/lou,min = lb/l_d = 0.33981258$   
 $su1 = 0.4 \cdot esu1\_nominal ((5.5), TBDY) = 0.032$

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

$For \text{ calculation of } esu1\_nominal \text{ and } y1, sh1, ft1, fy1, \text{ it is considered}$   
 $characteristic \text{ value } fsy1 = fs1 / 1.2, \text{ from table } 5.1, TBDY.$

$y1, sh1, ft1, fy1, \text{ are also multiplied by } Min(1, 1.25 \cdot (lb/l_d)^{2/3}), \text{ from } 10.3.5, ASCE 41-17.$

$\text{with } fs1 = (fs,jacket \cdot Asl,ten,jacket + fs,core \cdot Asl,ten,core) / Asl,ten = 399.8226$

$\text{with } Es1 = (Es,jacket \cdot Asl,ten,jacket + Es,core \cdot Asl,ten,core) / Asl,ten = 200000.00$

$y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$

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

$lo/lou,min = lb/l_b,min = 0.33981258$   
 $su2 = 0.4 \cdot esu2\_nominal ((5.5), TBDY) = 0.032$

$From \text{ table } 5A.1, TBDY: esu2\_nominal = 0.08,$

$For \text{ calculation of } esu2\_nominal \text{ and } y2, sh2, ft2, fy2, \text{ it is considered}$   
 $characteristic \text{ value } fsy2 = fs2 / 1.2, \text{ from table } 5.1, TBDY.$

$y1, sh1, ft1, fy1, \text{ are also multiplied by } Min(1, 1.25 \cdot (lb/l_d)^{2/3}), \text{ from } 10.3.5, ASCE 41-17.$

$\text{with } fs2 = (fs,jacket \cdot Asl,com,jacket + fs,core \cdot Asl,com,core) / Asl,com = 399.8226$

$\text{with } Es2 = (Es,jacket \cdot Asl,com,jacket + Es,core \cdot Asl,com,core) / Asl,com = 200000.00$

$yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$

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

$l_o/l_{ou,min} = l_b/l_d = 0.33981258$   
 $s_{uv} = 0.4 * e_{suv\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $e_{suv\_nominal} = 0.08$ ,  
 considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $e_{suv\_nominal}$  and  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $f_{yv}$ , it is considered  
 characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1$ ,  $ft_1$ ,  $f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $f_{sv} = (f_{sj\_jacket} * A_{sl,mid,jacket} + f_{sj,mid} * A_{sl,mid,core}) / A_{sl,mid} = 422.7114$   
 with  $E_{sv} = (E_{sj\_jacket} * A_{sl,mid,jacket} + E_{sj,mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b * d) * (f_{s1} / f_c) = 0.0752324$   
 $2 = A_{sl,com} / (b * d) * (f_{s2} / f_c) = 0.0752324$   
 $v = A_{sl,mid} / (b * d) * (f_{sv} / f_c) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{sl,ten} / (b * d) * (f_{s1} / f_c) = 0.09371431$   
 $2 = A_{sl,com} / (b * d) * (f_{s2} / f_c) = 0.09371431$   
 $v = A_{sl,mid} / (b * d) * (f_{sv} / f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c\_jacket} * Area\_jacket + f'_{c\_core} * Area\_core) / Area\_section = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$

where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

Calculation of  $Mu_{2+}$

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

$u = 1.9632832E-005$

$Mu = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$   
 $N = 7506.808$   
 $f_c = 33.00$   
 $\alpha (5A.5, TBDY) = 0.002$   
 Final value of  $\alpha$ :  $\alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.01393923$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\alpha = 0.01393923$   
 $\alpha_e ((5.4c), TBDY) = \alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$   
 where  $f = \alpha * \rho_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06628267$   
 $\alpha_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
 From EC8 A.4.4.3(6),  $\rho_f = 2t_f/bw = 0.00451556$   
 $bw = 450.00$   
 effective stress from (A.35),  $f_{fe} = 881.8461$

$f_y = 0.06628267$   
 $\alpha_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
 From EC8 A.4.4.3(6),  $\rho_f = 2t_f/bw = 0.00451556$   
 $bw = 450.00$   
 effective stress from (A.35),  $f_{fe} = 881.8461$

$R = 40.00$   
 Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{f,f} = 0.015$   
 $\alpha_{se} ((5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.14546167$   
 $\alpha_{se1} = 0.12623274$   
 $b_{o,1} = 390.00$   
 $h_{o,1} = 390.00$   
 $b_{i2,1} = 608400.00$   
 $\alpha_{se2} = \text{Max}(\alpha_{se1}, \alpha_{se2}) = 0.18853448$   
 $b_{o,2} = 242.00$   
 $h_{o,2} = 242.00$   
 $b_{i2,2} = 234256.00$   
 $\rho_{sh, \min} * f_{ywe} = \text{Min}(\rho_{sh,x} * f_{ywe}, \rho_{sh,y} * f_{ywe}) = 1.38262$

Expression ((5.4d), TBDY) for  $\rho_{sh, \min} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\rho_{sh,x} * f_{ywe} = \rho_{sh1} * f_{ywe1} + \rho_{sh2} * f_{ywe2} = 1.38262$   
 $\rho_{sh1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir\_1} * n_{s\_1} = 157.0796$   
 No stirrups,  $n_{s\_1} = 2.00$   
 $h_1 = 450.00$   
 $\rho_{sh2} \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir\_2} * n_{s\_2} = 100.531$   
 No stirrups,  $n_{s\_2} = 2.00$   
 $h_2 = 250.00$

$\rho_{sh,y} * f_{ywe} = \rho_{sh1} * f_{ywe1} + \rho_{sh2} * f_{ywe2} = 1.38262$   
 $\rho_{sh1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir\_1} * n_{s\_1} = 157.0796$   
 No stirrups,  $n_{s\_1} = 2.00$   
 $h_1 = 450.00$   
 $\rho_{sh2} \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir\_2} * n_{s\_2} = 100.531$   
 No stirrups,  $n_{s\_2} = 2.00$   
 $h_2 = 250.00$

$A_{sec} = 202500.00$   
 $s_1 = 300.00$   
 $s_2 = 120.00$



```

fywe1 = 694.45
fywe2 = 555.55
fce = 33.00
From ((5.A.5), TBDY), TBDY: cc = 0.00305417
c = confinement factor = 1.10542
y1 = 0.00152175
sh1 = 0.0048696
ft1 = 479.7871
fy1 = 399.8226
su1 = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258
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, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 399.8226
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00152175
sh2 = 0.0048696
ft2 = 479.7871
fy2 = 399.8226
su2 = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.33981258
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, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00152175
shv = 0.0048696
ftv = 507.2537
fyv = 422.7114
suv = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258
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, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
c = confinement factor = 1.10542
1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353

```

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

--->  
v < vs,y2 - LHS eq.(4.5) is satisfied  
--->  
su (4.9) = 0.16791801  
Mu = MRc (4.14) = 2.2193E+008  
u = su (4.1) = 1.9632832E-005

Calculation of ratio lb/l<sub>d</sub>

Lap Length: lb/l<sub>d</sub> = 0.33981258  
lb = 300.00  
ld = 882.8396  
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
= 1  
db = 16.66667  
Mean strength value of all re-bars: fy = 655.558  
Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)  
t = 1.00  
s = 0.80  
e = 1.00  
cb = 25.00  
Ktr = 2.86234  
Atr = Min(Atr\_x,Atr\_y) = 257.6106  
where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y loxal axis  
s = Max(s\_external,s\_internal) = 300.00  
n = 12.00

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:  
u = 1.9632832E-005  
Mu = 2.2193E+008

with full section properties:

b = 450.00  
d = 407.00  
d' = 43.00  
v = 0.00124204  
N = 7506.808  
fc = 33.00  
co (5A.5, TBDY) = 0.002  
Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01393923  
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY: cu = 0.01393923  
we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+Min( fx, fy) = 0.06811101  
where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.06628267  
af = 0.54930041  
b = 450.00  
h = 450.00  
From EC8 A4.4.3(6), pf = 2tf/bw = 0.00451556  
bw = 450.00  
effective stress from (A.35), ffe = 881.8461

fy = 0.06628267  
af = 0.54930041  
b = 450.00  
h = 450.00

From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $ff,e = 881.8461$

$R = 40.00$   
Effective FRP thickness,  $tf = NL*t*\cos(b1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $ase((5.4d), TBDY) = (ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.14546167$   
 $ase1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi2_1 = 608400.00$   
 $ase2 = \max(ase1, ase2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi2_2 = 234256.00$   
 $psh_{min}*F_{ywe} = \min(psh_x*F_{ywe}, psh_y*F_{ywe}) = 1.38262$

Expression ((5.4d), TBDY) for  $psh_{min}*F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 1.38262$   
 $ps1 \text{ (external)} = (Ash1*h1/s1)/A_{sec} = 0.00116355$   
 $Ash1 = Astir_1*ns_1 = 157.0796$   
No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2*h2/s2)/A_{sec} = 0.00103427$   
 $Ash2 = Astir_2*ns_2 = 100.531$   
No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

$psh_y*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 1.38262$   
 $ps1 \text{ (external)} = (Ash1*h1/s1)/A_{sec} = 0.00116355$   
 $Ash1 = Astir_1*ns_1 = 157.0796$   
No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2*h2/s2)/A_{sec} = 0.00103427$   
 $Ash2 = Astir_2*ns_2 = 100.531$   
No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

$A_{sec} = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$

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

$lo/lo_{u,min} = lb/ld = 0.33981258$   
 $su1 = 0.4*esu1_{nominal}((5.5), TBDY) = 0.032$

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, ASCE 41-17.

with  $fs1 = (fs_{jacket}*A_{sl,ten,jacket} + fs_{core}*A_{sl,ten,core})/A_{sl,ten} = 399.8226$

with  $Es1 = (Es_{jacket}*A_{sl,ten,jacket} + Es_{core}*A_{sl,ten,core})/A_{sl,ten} = 200000.00$

$y2 = 0.00152175$

```

sh2 = 0.0048696
ft2 = 479.7871
fy2 = 399.8226
su2 = 0.0066488
    using (30) in Biskinis/Fardis (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 = 0.33981258
    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, ASCE 41-17.
    with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226
    with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
    yv = 0.00152175
    shv = 0.0048696
    ftv = 507.2537
    fyv = 422.7114
    suv = 0.0066488
    using (30) in Biskinis/Fardis (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 = 0.33981258
    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, ASCE 41-17.
    with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
    2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
    v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438
    and confined core properties:
    b = 390.00
    d = 377.00
    d' = 13.00
    fcc (5A.2, TBDY) = 36.47874
    cc (5A.5, TBDY) = 0.00305417
    c = confinement factor = 1.10542
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
    2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
    v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353
    Case/Assumption: Unconfined full section - Steel rupture
    ' satisfies Eq. (4.3)
    --->
    v < vs,y2 - LHS eq.(4.5) is satisfied
    --->
    su (4.9) = 0.16791801
    Mu = MRc (4.14) = 2.2193E+008
    u = su (4.1) = 1.9632832E-005

```

#### Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.33981258
lb = 300.00
ld = 882.8396
    Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
    = 1
    db = 16.66667
    Mean strength value of all re-bars: fy = 655.558
    Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.98765, but fc'^0.5 <=
    8.3 MPa (22.5.3.1, ACI 318-14)
    t = 1.00

```

$s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $Ktr = 2.86234$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$   
 $n = 12.00$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$

Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$V_{Col0} = 567563.724$

$knl = 1$  (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)

Mean concrete strength:  $fc' = (fc'_{\text{jacket}} * \text{Area}_{\text{jacket}} + fc'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$ , but  $fc'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.0463738E-012$

$V_u = 2.7162834E-031$

$d = 0.8 * h = 360.00$

$N_u = 7506.808$

$A_g = 202500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 300.00$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$s/d = 0.83333333$

$V_{s2} = 74466.637$  is calculated for core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 120.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.60$

$V_f ((11-3)-(11.4), \text{ACI 440}) = 214457.247$

$f = 0.95$ , 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  $\theta$  is the angle of the crack direction (see KANEPE).

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

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

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:

total thickness per orientation,  $tf_1 = NL * t / \text{NoDir} = 1.016$

$dfv = d$  (figure 11.2, ACI 440) = 407.00

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

$E_f = 64828.00$

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

with  $fu = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$

$bw = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$

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

VCol0 = 567563.724

knl = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 1.0463738E-012

Vu = 2.7162834E-031

d = 0.8\*h = 360.00

Nu = 7506.808

Ag = 202500.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 144280.365

where:

Vs1 = 69813.729 is calculated for jacket, with:

d = 360.00

Av = 157079.633

fy = 555.56

s = 300.00

Vs1 is multiplied by Col1 = 0.66666667

s/d = 0.83333333

Vs2 = 74466.637 is calculated for core, with:

d = 200.00

Av = 100530.965

fy = 444.44

s = 120.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.60

Vf ((11-3)-(11.4), ACI 440) = 214457.247

f = 0.95, for fully-wrapped sections

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

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

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

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

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

total thickness per orientation,  $tf1 = NL \cdot t / \text{NoDir} = 1.016$

dfv = d (figure 11.2, ACI 440) = 407.00

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 <= 579413.096

bw = 450.00

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -3.5352E+007$

Shear Force,  $V_2 = -11781.223$

Shear Force,  $V_3 = 2.6378276E-013$

Axial Force,  $F = -7502.094$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 1137.257$

-Compression:  $As_c = 1539.38$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

-Middle:  $As_{mid} = 402.1239$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

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

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

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

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten,core} = 307.8761$

-Compression:  $As_{c,com,core} = 307.8761$

-Middle:  $As_{mid,core} = 0.00$

Mean Diameter of Tension Reinforcement,  $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = * u = 0.03835042$

$u = y + p = 0.04511814$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.006502$  ((4.29), Biskinis Phd))  
 $M_y = 1.7613E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3000.708  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.7095E+013$   
 $factor = 0.30$   
 $A_g = 202500.00$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$   
 $N = 7502.094$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 9.0315E+013$

#### Calculation of Yielding Moment $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 6.1806717E-006$   
 with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 374.3546$   
 $d = 407.00$   
 $y = 0.25591399$   
 $A = 0.01472387$   
 $B = 0.00818866$   
 with  $p_t = 0.00430549$   
 $p_c = 0.00620943$   
 $p_v = 0.0021956$   
 $N = 7502.094$   
 $b = 450.00$   
 $" = 0.10565111$   
 $y_{comp} = 2.2127287E-005$   
 with  $f_c' (12.3, (ACI 440)) = 34.40847$   
 $f_c = 33.00$   
 $f_l = 0.82797802$   
 $b = 450.00$   
 $h = 450.00$   
 $A_g = 202500.00$   
 From (12.9), ACI 440:  $k_a = 0.54261599$   
 $g = p_t + p_c + p_v = 0.01461445$   
 $r_c = 40.00$   
 $A_e / A_c = 0.54261599$   
 Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.25471852$   
 $A = 0.01452517$   
 $B = 0.00807924$   
 with  $E_s = 200000.00$

#### Calculation of ratio $I_b / I_d$

Lap Length:  $I_d / I_{d,min} = 0.42476573$   
 $I_b = 300.00$   
 $I_d = 706.2717$   
 Calculation of  $I$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 524.4464$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$



$cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$   
 where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$   
 $n = 12.00$

- Calculation of  $p$  -

From table 10-8:  $p = 0.03861614$

with:

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

shear control ratio  $V_y E / V_{ColOE} = 0.26068017$

$d = d_{\text{external}} = 407.00$

$s = s_{\text{external}} = 0.00$

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00430549$

jacket:  $s_1 = A_{v1} \cdot h_1 / (s_1 \cdot A_g) = 0.00116355$

$A_{v1} = 157.0796$ , is the total area of all stirrups parallel to loading (shear) direction

$h_1 = 450.00$

$s_1 = 300.00$

core:  $s_2 = A_{v2} \cdot h_2 / (s_2 \cdot A_g) = 0.00103427$

$A_{v2} = 100.531$ , is the total area of all stirrups parallel to loading (shear) direction

$h_2 = 250.00$

$s_2 = 120.00$

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.

For the normalisation  $f_s$  of jacket is used.

$NUD = 7502.094$

$A_g = 202500.00$

$f_{cE} = (f_{c\_jacket} \cdot \text{Area\_jacket} + f_{c\_core} \cdot \text{Area\_core}) / \text{section\_area} = 28.98765$

$f_{yIE} = (f_{y\_ext\_Long\_Reinf} \cdot \text{Area\_ext\_Long\_Reinf} + f_{y\_int\_Long\_Reinf} \cdot \text{Area\_int\_Long\_Reinf}) / \text{Area\_Tot\_Long\_Rein} = 529.9972$

$f_{ytE} = (f_{y\_ext\_Trans\_Reinf} \cdot s_1 + f_{y\_int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 503.2682$

$\rho_l = \text{Area\_Tot\_Long\_Rein} / (b \cdot d) = 0.01461445$

$b = 450.00$

$d = 407.00$

$f_{cE} = 28.98765$

End Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (a)

## Calculation No. 13

column C1, Floor 1

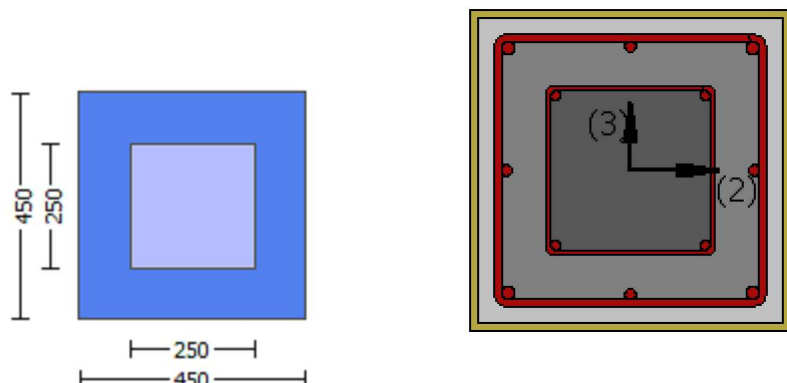
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

New material: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material: Steel Strength,  $f_s = f_{sm} = 555.56$

Existing Column

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

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

#####

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_o = l_b = 300.00$   
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $\epsilon_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i: 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

EDGE -A-  
 Bending Moment,  $M_a = -3.5352E+007$   
 Shear Force,  $V_a = -11781.223$   
 EDGE -B-  
 Bending Moment,  $M_b = 0.09202348$   
 Shear Force,  $V_b = 11781.223$   
 BOTH EDGES  
 Axial Force,  $F = -7502.094$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{sl,t} = 0.00$   
   -Compression:  $A_{sl,c} = 2676.637$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{sl,ten} = 1137.257$   
   -Compression:  $A_{sl,com} = 1137.257$   
   -Middle:  $A_{sl,mid} = 402.1239$   
 Mean Diameter of Tension Reinforcement,  $D_{bL,ten} = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = V_n = 447100.239$   
 $V_n ((10.3), ASCE 41-17) = k_n l^* V_{CoI0} = 526000.281$   
 $V_{CoI} = 526000.281$   
 $k_n l = 1.00$   
 $displacement\_ductility\_demand = 0.30104645$

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)  
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 22.22222$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 0.09202348$   
 $V_u = 11781.223$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7502.094$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 129852.496$   
 where:  
 $V_{s1} = 62831.853$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$

Vs2 = 67020.643 is calculated for core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 400.00$$

$$s = 120.00$$

Vs2 is multiplied by Col2 = 1.00

$$s/d = 0.60$$

$$V_f((11-3)-(11.4), \text{ACI 440}) = 214457.247$$

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,  $t_{f1} = N_L * t / \text{NoDir} = 1.016$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 407.00$$

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 507312.442$$

$$b_w = 450.00$$

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  $\theta = 0.00019569$

$$y = (M_y * L_s / 3) / E_{eff} = 0.00065005 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 1.7613E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 300.00$$

$$\text{From table 10.5, ASCE 41_17: } E_{eff} = \text{factor} * E_c * I_g = 2.7095E+013$$

$$\text{factor} = 0.30$$

$$A_g = 202500.00$$

$$\text{Mean concrete strength: } f'_c = (f'_c_{\text{jacket}} * \text{Area}_{\text{jacket}} + f'_c_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$$

$$N = 7502.094$$

$$E_c * I_g = E_{c_{\text{jacket}}} * I_{g_{\text{jacket}}} + E_{c_{\text{core}}} * I_{g_{\text{core}}} = 9.0315E+013$$

Calculation of Yielding Moment  $M_y$

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

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

$$y_{\text{ten}} = 6.1806717E-006$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 374.3546$$

$$d = 407.00$$

$$y = 0.25591399$$

$$A = 0.01472387$$

$$B = 0.00818866$$

$$\text{with } p_t = 0.00620943$$

$$p_c = 0.00620943$$

$$p_v = 0.0021956$$

$$N = 7502.094$$

$$b = 450.00$$

$$\mu = 0.10565111$$

$$y_{\text{comp}} = 2.2127287E-005$$

$$\text{with } f'_c * (12.3, (\text{ACI 440})) = 34.40847$$

$$f_c = 33.00$$

$$f_l = 0.82797802$$

$$b = 450.00$$

$h = 450.00$   
 $A_g = 202500.00$   
 From (12.9), ACI 440:  $k_a = 0.54261599$   
 $g = p_t + p_c + p_v = 0.01461445$   
 $rc = 40.00$   
 $A_e/A_c = 0.54261599$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.25471852$   
 $A = 0.01452517$   
 $B = 0.00807924$   
 with  $E_s = 200000.00$

Calculation of ratio  $I_b/I_d$

Lap Length:  $I_d/I_{d,min} = 0.42476573$

$I_b = 300.00$

$I_d = 706.2717$

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

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$

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

$s = \max(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

End Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 14

column C1, Floor 1

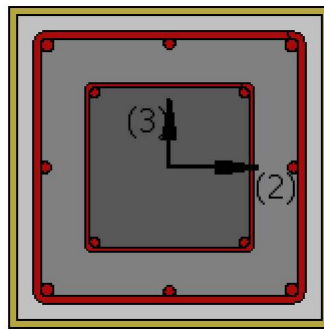
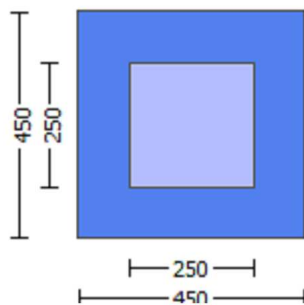
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\phi_r$ )

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

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

#####

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $ef_u = 0.01$

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: 3

EDGE -A-

Shear Force,  $V_a = 2.0531359E-031$

EDGE -B-

Shear Force,  $V_b = -2.0531359E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_{lt} = 0.00$

-Compression:  $As_{lc} = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$   
with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.2193E+008$

$Mu_{1+} = 2.2193E+008$ , 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

$Mu_{1-} = 2.2193E+008$ , 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.2193E+008$

$Mu_{2+} = 2.2193E+008$ , 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

$Mu_{2-} = 2.2193E+008$ , 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:

$\phi_u = 1.9632832E-005$

$M_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$\alpha_0$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01393923$

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

From (5.4b), TBDY:  $\phi_u = 0.01393923$

we ((5.4c), TBDY) =  $\alpha_{se} * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.06811101$

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

$\phi_x = 0.06628267$

$\alpha_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $\rho_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$f_y = 0.06628267$   
 $a_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
 From EC8 A4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$   
 $b_w = 450.00$   
 effective stress from (A.35),  $f_{f,e} = 881.8461$

$R = 40.00$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $a_{se} ((5.4d), TBDY) = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int}) / A_{sec} = 0.14546167$   
 $a_{se1} = 0.12623274$   
 $bo\_1 = 390.00$   
 $ho\_1 = 390.00$   
 $bi2\_1 = 608400.00$   
 $a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$   
 $bo\_2 = 242.00$   
 $ho\_2 = 242.00$   
 $bi2\_2 = 234256.00$   
 $p_{sh,min} \cdot F_{ywe} = \text{Min}(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 1.38262$

Expression ((5.4d), TBDY) for  $p_{sh,min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 1.38262$   
 $p_{s1} \text{ (external)} = (A_{sh1} \cdot h_1 / s_1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir\_1} \cdot n_{s\_1} = 157.0796$   
 No stirrups,  $n_{s\_1} = 2.00$   
 $h_1 = 450.00$   
 $p_{s2} \text{ (internal)} = (A_{sh2} \cdot h_2 / s_2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir\_2} \cdot n_{s\_2} = 100.531$   
 No stirrups,  $n_{s\_2} = 2.00$   
 $h_2 = 250.00$

$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 1.38262$   
 $p_{s1} \text{ (external)} = (A_{sh1} \cdot h_1 / s_1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir\_1} \cdot n_{s\_1} = 157.0796$   
 No stirrups,  $n_{s\_1} = 2.00$   
 $h_1 = 450.00$   
 $p_{s2} \text{ (internal)} = (A_{sh2} \cdot h_2 / s_2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir\_2} \cdot n_{s\_2} = 100.531$   
 No stirrups,  $n_{s\_2} = 2.00$   
 $h_2 = 250.00$

$A_{sec} = 202500.00$   
 $s_1 = 300.00$   
 $s_2 = 120.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $c_c = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y_1 = 0.00152175$   
 $sh_1 = 0.0048696$   
 $ft_1 = 479.7871$   
 $fy_1 = 399.8226$   
 $su_1 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lo_{u,min} = lb/ld = 0.33981258$   
 $su_1 = 0.4 \cdot esu_{1,nominal} ((5.5), TBDY) = 0.032$   
 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  $f_{sy1} = f_{s1}/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $f_{s1} = (f_{sjacket} \cdot A_{s,ten,jacket} + f_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 399.8226$   
with  $E_{s1} = (E_{sjacket} \cdot A_{s,ten,jacket} + E_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.33981258$   
 $su2 = 0.4 \cdot esu2\_nominal \cdot ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $f_{s2} = (f_{sjacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core})/A_{s,com} = 399.8226$   
with  $E_{s2} = (E_{sjacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core})/A_{s,com} = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.33981258$   
 $suv = 0.4 \cdot esuv\_nominal \cdot ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $f_{sv} = (f_{sjacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 422.7114$   
with  $E_{sv} = (E_{sjacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 200000.00$   
 $1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0752324$   
 $2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0752324$   
 $v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} \text{ (5A.2, TBDY)} = 36.47874$   
 $cc \text{ (5A.5, TBDY)} = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.09371431$   
 $2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09371431$   
 $v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su \text{ (4.9)} = 0.16791801$   
 $Mu = MR_c \text{ (4.14)} = 2.2193E+008$   
 $u = su \text{ (4.1)} = 1.9632832E-005$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$   
 $l_b = 300.00$   
 $l_d = 882.8396$

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

$db = 16.66667$   
Mean strength value of all re-bars:  $fy = 655.558$   
Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$   
where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \max(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$

#### Calculation of $\mu_1$ -

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

$\mu = 1.9632832E-005$

$\mu_1 = 2.2193E+008$

with full section properties:

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.00124204$   
 $N = 7506.808$   
 $fc = 33.00$   
 $\alpha_1$  (5A.5, TBDY) = 0.002  
Final value of  $\mu_1$ :  $\mu_1^* = \text{shear\_factor} \cdot \max(\mu_1, \mu_2) = 0.01393923$   
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY:  $\mu_1 = 0.01393923$   
 $\mu_2$  ((5.4c), TBDY) =  $\alpha_1 \cdot \min(f_{ywe}/f_{ce} + \min(f_x, f_y)) = 0.06811101$   
where  $f = \alpha_1 \cdot p_f \cdot f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06628267$   
 $\alpha_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $f_{fe} = 881.8461$

$f_y = 0.06628267$   
 $\alpha_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $f_{fe} = 881.8461$

$R = 40.00$   
Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_f = 0.015$   
 $\alpha_{se}$  ((5.4d), TBDY) =  $(\alpha_{se1} \cdot A_{ext} + \alpha_{se2} \cdot A_{int}) / A_{sec} = 0.14546167$   
 $\alpha_{se1} = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi_2 = 608400.00$   
 $\alpha_{se2} = \max(\alpha_{se1}, \alpha_{se2}) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$

```

bi2_2 = 234256.00
psh,min*Fywe = Min(psh,x*Fywe , psh,y*Fywe) = 1.38262
Expression ((5.4d), TBDY) for psh,min*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without
earthquake detailing (90° closed stirrups)
-----
psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 1.38262
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00116355
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 450.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00103427
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 250.00
-----
psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 1.38262
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00116355
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 450.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00103427
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 250.00
-----
Asec = 202500.00
s1 = 300.00
s2 = 120.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00
From ((5.A5), TBDY), TBDY: cc = 0.00305417
c = confinement factor = 1.10542
y1 = 0.00152175
sh1 = 0.0048696
ft1 = 479.7871
fy1 = 399.8226
su1 = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.33981258
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, ASCE 41-17.
with fs1 = (fs,jacket*Asl,tens,jacket + fs,core*Asl,tens,core)/Asl,tens = 399.8226
with Es1 = (Es,jacket*Asl,tens,jacket + Es,core*Asl,tens,core)/Asl,tens = 200000.00
y2 = 0.00152175
sh2 = 0.0048696
ft2 = 479.7871
fy2 = 399.8226
su2 = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.33981258
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, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00152175
shv = 0.0048696

```

```

ftv = 507.2537
fyv = 422.7114
suv = 0.0066488
    using (30) in Biskinis/Fardis (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 = 0.33981258
    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, ASCE 41-17.
    with fsv = (fsjacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
    2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
    v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
    c = confinement factor = 1.10542
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
    2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
    v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008
u = su (4.1) = 1.9632832E-005
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.33981258
lb = 300.00
ld = 882.8396
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.98765, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.86234
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 300.00
n = 12.00
-----
-----
-----
Calculation of Mu2+
-----
-----
-----
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.9632832E-005

```

$$\mu = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, \alpha) = 0.01393923$$

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

$$\text{From (5.4b), TB DY: } \mu = 0.01393923$$

$$\mu_e ((5.4c), \text{TB DY}) = \alpha * \mu_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

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

$$f_x = 0.06628267$$

$$\alpha f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_f = 2t_f/bw = 0.00451556$$

$$bw = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$f_y = 0.06628267$$

$$\alpha f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_f = 2t_f/bw = 0.00451556$$

$$bw = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

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

$$\alpha_e ((5.4d), \text{TB DY}) = (\alpha_e1 * A_{ext} + \alpha_e2 * A_{int}) / A_{sec} = 0.14546167$$

$$\alpha_e1 = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i2,1} = 608400.00$$

$$\alpha_e2 = \text{Max}(\alpha_e1, \alpha_e2) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i2,2} = 234256.00$$

$$\mu_{\min} * f_{ywe} = \text{Min}(\mu_{\min,x} * f_{ywe}, \mu_{\min,y} * f_{ywe}) = 1.38262$$

Expression ((5.4d), TB DY) for  $\mu_{\min} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\mu_{\min,x} * f_{ywe} = \mu_{\min,1} * f_{ywe1} + \mu_{\min,2} * f_{ywe2} = 1.38262$$

$$\mu_{\min,1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{\text{stir}_1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$\mu_{\min,2} (\text{internal}) = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{\text{stir}_2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h_2 = 250.00$$

$$\mu_{\min,y} * f_{ywe} = \mu_{\min,1} * f_{ywe1} + \mu_{\min,2} * f_{ywe2} = 1.38262$$

$$\mu_{\min,1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{\text{stir}_1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$\mu_{\min,2} (\text{internal}) = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{\text{stir}_2} * n_{s,2} = 100.531$$

No stirrups, ns\_2 = 2.00  
h2 = 250.00

Asec = 202500.00

s1 = 300.00

s2 = 120.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5A5), TBDY), TBDY: cc = 0.00305417

c = confinement factor = 1.10542

y1 = 0.00152175

sh1 = 0.0048696

ft1 = 479.7871

fy1 = 399.8226

su1 = 0.0066488

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

lo/lou,min = lb/lb = 0.33981258

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, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175

sh2 = 0.0048696

ft2 = 479.7871

fy2 = 399.8226

su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.33981258

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, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 399.8226

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00152175

shv = 0.0048696

ftv = 507.2537

fyv = 422.7114

suv = 0.0066488

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

lo/lou,min = lb/lb = 0.33981258

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, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 422.7114

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0752324

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.0752324

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.02812438

and confined core properties:

b = 390.00

d = 377.00

d' = 13.00

```

fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
c = confinement factor = 1.10542
1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)

```

```

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

```

```

--->
su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008
u = su (4.1) = 1.9632832E-005

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.33981258
lb = 300.00
ld = 882.8396
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.98765, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.86234
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 300.00
n = 12.00

```

Calculation of Mu2-

```

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.9632832E-005
Mu = 2.2193E+008

```

with full section properties:

```

b = 450.00
d = 407.00
d' = 43.00
v = 0.00124204
N = 7506.808
fc = 33.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01393923
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01393923
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.06811101
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
fx = 0.06628267
af = 0.54930041
b = 450.00
h = 450.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556
bw = 450.00

```

effective stress from (A.35),  $f_{f,e} = 881.8461$

$f_y = 0.06628267$

$a_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$a_{se} ((5.4d), TBDY) = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int}) / A_{sec} = 0.14546167$

$a_{se1} = 0.12623274$

$bo_1 = 390.00$

$ho_1 = 390.00$

$bi2_1 = 608400.00$

$a_{se2} = \max(a_{se1}, a_{se2}) = 0.18853448$

$bo_2 = 242.00$

$ho_2 = 242.00$

$bi2_2 = 234256.00$

$p_{sh,min} \cdot F_{ywe} = \min(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 1.38262$

Expression ((5.4d), TBDY) for  $p_{sh,min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{s2} \cdot F_{ywe2} = 1.38262$

$p_{s1} \text{ (external)} = (A_{sh1} \cdot h_1 / s_1) / A_{sec} = 0.00116355$

$A_{sh1} = A_{stir_1} \cdot n_{s_1} = 157.0796$

No stirrups,  $n_{s_1} = 2.00$

$h_1 = 450.00$

$p_{s2} \text{ (internal)} = (A_{sh2} \cdot h_2 / s_2) / A_{sec} = 0.00103427$

$A_{sh2} = A_{stir_2} \cdot n_{s_2} = 100.531$

No stirrups,  $n_{s_2} = 2.00$

$h_2 = 250.00$

$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{s2} \cdot F_{ywe2} = 1.38262$

$p_{s1} \text{ (external)} = (A_{sh1} \cdot h_1 / s_1) / A_{sec} = 0.00116355$

$A_{sh1} = A_{stir_1} \cdot n_{s_1} = 157.0796$

No stirrups,  $n_{s_1} = 2.00$

$h_1 = 450.00$

$p_{s2} \text{ (internal)} = (A_{sh2} \cdot h_2 / s_2) / A_{sec} = 0.00103427$

$A_{sh2} = A_{stir_2} \cdot n_{s_2} = 100.531$

No stirrups,  $n_{s_2} = 2.00$

$h_2 = 250.00$

$A_{sec} = 202500.00$

$s_1 = 300.00$

$s_2 = 120.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $c_c = 0.00305417$

$c$  = confinement factor = 1.10542

$y_1 = 0.00152175$

$sh_1 = 0.0048696$

$ft_1 = 479.7871$

$fy_1 = 399.8226$

$su_1 = 0.0066488$

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

$lo/lou,min = lb/ld = 0.33981258$

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

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



For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs1 = (fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 399.8226$   
 with  $Es1 = (Es_{jacket} \cdot Asl_{ten,jacket} + Es_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{ou,min} = lb/lb_{min} = 0.33981258$   
 $su2 = 0.4 \cdot esu2\_nominal \cdot ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
 For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 399.8226$   
 with  $Es2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{ou,min} = lb/ld = 0.33981258$   
 $suv = 0.4 \cdot esuv\_nominal \cdot ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 422.7114$   
 with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs1/fc) = 0.0752324$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs2/fc) = 0.0752324$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv/fc) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs1/fc) = 0.09371431$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs2/fc) = 0.09371431$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv/fc) = 0.03503353$

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

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.33981258$   
 $lb = 300.00$   
 $ld = 882.8396$   
 Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$\lambda = 1$   
 $db = 16.66667$   
Mean strength value of all re-bars:  $f_y = 655.558$   
Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot Area\_jacket + f'_{c\_core} \cdot Area\_core) / Area\_section = 28.98765$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \min(A_{tr\_x}, A_{tr\_y}) = 257.6106$   
where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \max(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$

Calculation of Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 567563.724$

Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$V_{Col0} = 567563.724$

$k_{nl} = 1$  (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)  
Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot Area\_jacket + f'_{c\_core} \cdot Area\_core) / Area\_section = 28.98765$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.4404090E-011$   
 $\nu_u = 2.0531359E-031$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f ((11-3)-(11.4), ACI 440) = 214457.247$   
 $f = 0.95$ , 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,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $bw = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$   
 $V_{Col0} = 567563.724$   
 $knl = 1$  (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)  
Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M / Vd = 2.00$   
 $\mu_u = 1.4404090E-011$   
 $V_u = 2.0531359E-031$   
 $d = 0.8 * h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f ((11-3)-(11.4), ACI 440) = 214457.247$   
 $f = 0.95$ , 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) = 407.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
with  $f_u = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $bw = 450.00$

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjrs

## Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

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

#####

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

## Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = -2.7162834E-031$

EDGE -B-

Shear Force,  $V_b = 2.7162834E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$   
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 2.2193\text{E}+008$

$\mu_{1+} = 2.2193\text{E}+008$ , 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

$\mu_{1-} = 2.2193\text{E}+008$ , 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 2.2193\text{E}+008$

$\mu_{2+} = 2.2193\text{E}+008$ , 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

$\mu_{2-} = 2.2193\text{E}+008$ , 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  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 1.9632832\text{E}-005$

$M_u = 2.2193\text{E}+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$\alpha_0$  (5A.5, TBDY) = 0.002

Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_s) = 0.01393923$

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

From (5.4b), TBDY:  $\mu_c = 0.01393923$

$\mu_s$  ((5.4c), TBDY) =  $\alpha_s * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$

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

$f_x = 0.06628267$

$\alpha_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$f_y = 0.06628267$

$\alpha_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{f,f} = 0.015$

$\alpha_s$  ((5.4d), TBDY) =  $(\alpha_{s1} * A_{ext} + \alpha_{s2} * A_{int})/A_{sec} = 0.14546167$

$\alpha_{s1} = 0.12623274$

$b_{o,1} = 390.00$

$h_{o,1} = 390.00$

$b_{i2,1} = 608400.00$

$ase2 = \text{Max}(ase1, ase2) = 0.18853448$   
 $bo\_2 = 242.00$   
 $ho\_2 = 242.00$   
 $bi2\_2 = 234256.00$   
 $psh, \min * Fywe = \text{Min}(psh, x * Fywe, psh, y * Fywe) = 1.38262$   
 Expression ((5.4d), TBDY) for  $psh, \min * Fywe$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh\_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 * ns\_1 = 157.0796$   
 No stirrups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 * ns\_2 = 100.531$   
 No stirrups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$psh\_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 * ns\_1 = 157.0796$   
 No stirrups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 * ns\_2 = 100.531$   
 No stirrups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$Asec = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $lo/lou, \min = lb/ld = 0.33981258$   
 $su1 = 0.4 * esu1\_nominal \text{ ((5.5), TBDY)} = 0.032$   
 From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
 For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs1 = (fs, \text{jacket} * Asl, \text{ten, jacket} + fs, \text{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 399.8226$   
 with  $Es1 = (Es, \text{jacket} * Asl, \text{ten, jacket} + Es, \text{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $lo/lou, \min = lb/lb, \min = 0.33981258$   
 $su2 = 0.4 * esu2\_nominal \text{ ((5.5), TBDY)} = 0.032$   
 From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
 For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs2 = (fs, \text{jacket} * Asl, \text{com, jacket} + fs, \text{core} * Asl, \text{com, core}) / Asl, \text{com} = 399.8226$

```

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00152175
shv = 0.0048696
ftv = 507.2537
fyv = 422.7114
suv = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258
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, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
c = confinement factor = 1.10542
1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008
u = su (4.1) = 1.9632832E-005
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.33981258
lb = 300.00
ld = 882.8396
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.98765, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.86234
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 300.00
n = 12.00
-----
-----
-----
Calculation of Mu1-
-----

```

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

$$u = 1.9632832E-005$$

$$Mu = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01393923$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.01393923$$

$$\phi_{ue} ((5.4c), TBDY) = \alpha \phi_u * \frac{f_{ywe}}{f_{ce}} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.06811101$$

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

$$\phi_{fx} = 0.06628267$$

$$\alpha_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f/bw = 0.00451556$$

$$bw = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$\phi_{fy} = 0.06628267$$

$$\alpha_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f/bw = 0.00451556$$

$$bw = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

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

$$\alpha_{se} ((5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$\alpha_{se1} = 0.12623274$$

$$b_{o\_1} = 390.00$$

$$h_{o\_1} = 390.00$$

$$b_{i2\_1} = 608400.00$$

$$\alpha_{se2} = \text{Max}(\alpha_{se1}, \alpha_{se2}) = 0.18853448$$

$$b_{o\_2} = 242.00$$

$$h_{o\_2} = 242.00$$

$$b_{i2\_2} = 234256.00$$

$$\phi_{psh,min} * F_{ywe} = \text{Min}(\phi_{psh,x} * F_{ywe}, \phi_{psh,y} * F_{ywe}) = 1.38262$$

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

$$\phi_{psh,x} * F_{ywe} = \phi_{psh1} * F_{ywe1} + \phi_{psh2} * F_{ywe2} = 1.38262$$

$$\phi_{ps1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir\_1} * n_{s\_1} = 157.0796$$

$$\text{No stirrups, } n_{s\_1} = 2.00$$

$$h_1 = 450.00$$

$$\phi_{ps2} (\text{internal}) = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir\_2} * n_{s\_2} = 100.531$$

$$\text{No stirrups, } n_{s\_2} = 2.00$$

$$h_2 = 250.00$$

$$\phi_{psh,y} * F_{ywe} = \phi_{psh1} * F_{ywe1} + \phi_{psh2} * F_{ywe2} = 1.38262$$

$$\phi_{ps1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir\_1} * n_{s\_1} = 157.0796$$

$$\text{No stirrups, } n_{s\_1} = 2.00$$



$h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 \cdot ns\_2 = 100.531$   
 $No \text{ stirups, } ns\_2 = 2.00$   
 $h2 = 250.00$

$Asec = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$

$fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$   
 $sh1 = 0.0048696$

$ft1 = 479.7871$   
 $fy1 = 399.8226$

$su1 = 0.0066488$

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

$lo/lou, min = lb/ld = 0.33981258$

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

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

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs\_jacket \cdot Asl, ten, jacket + fs\_core \cdot Asl, ten, core) / Asl, ten = 399.8226$

with  $Es1 = (Es\_jacket \cdot Asl, ten, jacket + Es\_core \cdot Asl, ten, core) / Asl, ten = 200000.00$

$y2 = 0.00152175$

$sh2 = 0.0048696$

$ft2 = 479.7871$

$fy2 = 399.8226$

$su2 = 0.0066488$

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

$lo/lou, min = lb/lb, min = 0.33981258$

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

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs\_jacket \cdot Asl, com, jacket + fs\_core \cdot Asl, com, core) / Asl, com = 399.8226$

with  $Es2 = (Es\_jacket \cdot Asl, com, jacket + Es\_core \cdot Asl, com, core) / Asl, com = 200000.00$

$yv = 0.00152175$

$shv = 0.0048696$

$ftv = 507.2537$

$fyv = 422.7114$

$suv = 0.0066488$

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

$lo/lou, min = lb/ld = 0.33981258$

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

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, ASCE 41-17.

with  $fsv = (fs\_jacket \cdot Asl, mid, jacket + fs\_mid \cdot Asl, mid, core) / Asl, mid = 422.7114$

with  $Esu = (Es\_jacket \cdot Asl, mid, jacket + Es\_mid \cdot Asl, mid, core) / Asl, mid = 200000.00$

$1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.0752324$

$2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.0752324$

$v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.02812438$

and confined core properties:

```

b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
c = confinement factor = 1.10542
1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)

```

```

--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008
u = su (4.1) = 1.9632832E-005

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.33981258
lb = 300.00
ld = 882.8396
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.98765, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.86234
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 300.00
n = 12.00

```

Calculation of Mu2+

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

```

u = 1.9632832E-005
Mu = 2.2193E+008

```

with full section properties:

```

b = 450.00
d = 407.00
d' = 43.00
v = 0.00124204
N = 7506.808
fc = 33.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01393923
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01393923
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.06811101
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
fx = 0.06628267
af = 0.54930041
b = 450.00

```

h = 450.00  
From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $ff,e = 881.8461$

fy = 0.06628267  
af = 0.54930041  
b = 450.00  
h = 450.00  
From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $ff,e = 881.8461$

R = 40.00  
Effective FRP thickness,  $tf = NL*t*Cos(b1) = 1.016$   
fu,f = 1055.00  
Ef = 64828.00  
u,f = 0.015  
 $ase ((5.4d), TBDY) = (ase1*Aext+ase2*Aint)/Asec = 0.14546167$   
ase1 = 0.12623274  
bo\_1 = 390.00  
ho\_1 = 390.00  
bi2\_1 = 608400.00  
 $ase2 = Max(ase1,ase2) = 0.18853448$   
bo\_2 = 242.00  
ho\_2 = 242.00  
bi2\_2 = 234256.00

psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 1.38262  
Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) =  $(Ash1*h1/s1)/Asec = 0.00116355$   
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) =  $(Ash2*h2/s2)/Asec = 0.00103427$   
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) =  $(Ash1*h1/s1)/Asec = 0.00116355$   
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) =  $(Ash2*h2/s2)/Asec = 0.00103427$   
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258
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, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 399.8226
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00152175
sh2 = 0.0048696
ft2 = 479.7871
fy2 = 399.8226
su2 = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.33981258
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, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00152175
shv = 0.0048696
ftv = 507.2537
fyv = 422.7114
suv = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258
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, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
c = confinement factor = 1.10542
1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008
u = su (4.1) = 1.9632832E-005

```

Calculation of ratio lb/d

Lap Length: lb/d = 0.33981258

$l_b = 300.00$   
 $l_d = 882.8396$   
 Calculation of  $l_b$ , min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 655.558$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$   
 where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$

Calculation of  $\mu_2$ -

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

$\mu = 1.9632832E-005$   
 $\mu_u = 2.2193E+008$

with full section properties:

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.00124204$   
 $N = 7506.808$   
 $f_c = 33.00$   
 $\alpha_1 (5A.5, \text{TBDY}) = 0.002$   
 Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} \cdot \text{Max}(\mu_u, \mu_c) = 0.01393923$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\mu_u = 0.01393923$   
 $\mu_{ue} ((5.4c), \text{TBDY}) = \alpha_1 \cdot \text{sh}_{min} \cdot f_{ywe} / f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.06811101$   
 where  $\mu_f = \alpha_1 \cdot p_f \cdot f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\mu_{fx} = 0.06628267$   
 $\alpha_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$   
 $b_w = 450.00$   
 effective stress from (A.35),  $f_{fe} = 881.8461$

$\mu_{fy} = 0.06628267$   
 $\alpha_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$   
 $b_w = 450.00$   
 effective stress from (A.35),  $f_{fe} = 881.8461$

$R = 40.00$   
 Effective FRP thickness,  $t_f = N L \cdot t \cdot \text{Cos}(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{f,f} = 0.015$   
 $\alpha_{se} ((5.4d), \text{TBDY}) = (\alpha_{se1} \cdot A_{ext} + \alpha_{se2} \cdot A_{int}) / A_{sec} = 0.14546167$   
 $\alpha_{se1} = 0.12623274$   
 $b_{o_1} = 390.00$   
 $h_{o_1} = 390.00$

$bi2\_1 = 608400.00$   
 $ase2 = \text{Max}(ase1, ase2) = 0.18853448$   
 $bo\_2 = 242.00$   
 $ho\_2 = 242.00$   
 $bi2\_2 = 234256.00$   
 $psh, \min * Fywe = \text{Min}(psh, x * Fywe, psh, y * Fywe) = 1.38262$   
 Expression ((5.4d), TBDY) for  $psh, \min * Fywe$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh\_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 * ns\_1 = 157.0796$   
 No stirrups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 * ns\_2 = 100.531$   
 No stirrups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$psh\_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 * ns\_1 = 157.0796$   
 No stirrups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 * ns\_2 = 100.531$   
 No stirrups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$Asec = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$

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

$lo/lou, \min = lb/ld = 0.33981258$

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

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

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1 / 1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs, \text{jacket} * Asl, \text{ten, jacket} + fs, \text{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 399.8226$

with  $Es1 = (Es, \text{jacket} * Asl, \text{ten, jacket} + Es, \text{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$

$y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$

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

$lo/lou, \min = lb/lb, \min = 0.33981258$

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

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2 / 1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_2 = (fs_{\text{jacket}} \cdot Asl_{\text{com,jacket}} + fs_{\text{core}} \cdot Asl_{\text{com,core}}) / Asl_{\text{com}} = 399.8226$$

$$\text{with } Es_2 = (Es_{\text{jacket}} \cdot Asl_{\text{com,jacket}} + Es_{\text{core}} \cdot Asl_{\text{com,core}}) / Asl_{\text{com}} = 200000.00$$

$$yv = 0.00152175$$

$$shv = 0.0048696$$

$$ftv = 507.2537$$

$$fyv = 422.7114$$

$$suv = 0.0066488$$
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  

$$lo/lo_{\text{min}} = lb/ld = 0.33981258$$

$$suv = 0.4 \cdot esuv_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$$
 From table 5A.1, TBDY:  $esuv_{\text{nominal}} = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{\text{nominal}}$  and  $yv, shv, ftv, fyv$ , 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, ASCE 41-17.  

$$\text{with } fsv = (fs_{\text{jacket}} \cdot Asl_{\text{mid,jacket}} + fs_{\text{mid}} \cdot Asl_{\text{mid,core}}) / Asl_{\text{mid}} = 422.7114$$

$$\text{with } Es_v = (Es_{\text{jacket}} \cdot Asl_{\text{mid,jacket}} + Es_{\text{mid}} \cdot Asl_{\text{mid,core}}) / Asl_{\text{mid}} = 200000.00$$

$$1 = Asl_{\text{ten}} / (b \cdot d) \cdot (fs_1 / fc) = 0.0752324$$

$$2 = Asl_{\text{com}} / (b \cdot d) \cdot (fs_2 / fc) = 0.0752324$$

$$v = Asl_{\text{mid}} / (b \cdot d) \cdot (fsv / fc) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$fcc (5A.2, \text{TBDY}) = 36.47874$$

$$cc (5A.5, \text{TBDY}) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = Asl_{\text{ten}} / (b \cdot d) \cdot (fs_1 / fc) = 0.09371431$$

$$2 = Asl_{\text{com}} / (b \cdot d) \cdot (fs_2 / fc) = 0.09371431$$

$$v = Asl_{\text{mid}} / (b \cdot d) \cdot (fsv / fc) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su (4.9) = 0.16791801$$

$$Mu = MRc (4.14) = 2.2193E+008$$

$$u = su (4.1) = 1.9632832E-005$$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.33981258$

$lb = 300.00$

$ld = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{\text{jacket}} \cdot Area_{\text{jacket}} + fc'_{\text{core}} \cdot Area_{\text{core}}) / Area_{\text{section}} = 28.98765$ , but  $fc'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

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

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$

$n = 12.00$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$

Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$V_{Col0} = 567563.724$

$k_{nl} = 1$  (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)

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.0463738E-012$

$\nu_u = 2.7162834E-031$

$d = 0.8 * h = 360.00$

$N_u = 7506.808$

$A_g = 202500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 300.00$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$s/d = 0.83333333$

$V_{s2} = 74466.637$  is calculated for core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 120.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.60$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 214457.247$

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 407.00

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$

$b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$

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

$V_{Col0} = 567563.724$

$k_{nl} = 1$  (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)

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.0463738E-012$

$\nu_u = 2.7162834E-031$



$d = 0.8 \cdot h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f ((11-3)-(11.4), ACI 440) = 214457.247$   
 $f = 0.95$ , 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  $V_f(a)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $b_w = 450.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
 At local axis: 2  
 -----

-----  
 Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1  
 At local axis: 2  
 Integration Section: (b)  
 Section Type: rcjrs

Constant Properties

-----  
 Knowledge Factor,  $\phi = 0.85$   
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.  
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
 Concrete Elasticity,  $E_c = 21019.039$   
 Steel Elasticity,  $E_s = 200000.00$   
 External Height,  $H = 450.00$   
 External Width,  $W = 450.00$

Internal Height, H = 250.00  
 Internal Width, W = 250.00  
 Cover Thickness, c = 25.00  
 Element Length, L = 3000.00  
 Primary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length lb = 300.00  
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness, t = 1.016  
 Tensile Strength, ffu = 1055.00  
 Tensile Modulus, Ef = 64828.00  
 Elongation, efu = 0.01  
 Number of directions, NoDir = 1  
 Fiber orientations, bi: 0.00°  
 Number of layers, NL = 1  
 Radius of rounding corners, R = 40.00

#### Stepwise Properties

Bending Moment, M = -2.5732098E-010  
 Shear Force, V2 = 11781.223  
 Shear Force, V3 = -2.6378276E-013  
 Axial Force, F = -7502.094  
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension: Aslt = 0.00  
   -Compression: Aslc = 2676.637  
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension: Asl,ten = 1137.257  
   -Compression: Asl,com = 1137.257  
   -Middle: Asl,mid = 402.1239  
 Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
   -Tension: Asl,ten,jacket = 829.3805  
   -Compression: Asl,com,jacket = 829.3805  
   -Middle: Asl,mid,jacket = 402.1239  
 Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
   -Tension: Asl,ten,core = 307.8761  
   -Compression: Asl,com,core = 307.8761  
   -Middle: Asl,mid,core = 0.00  
 Mean Diameter of Tension Reinforcement, DbL = 16.80

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = \frac{1}{2} u = 0.03558642$   
 $u = y + p = 0.04186638$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00325023$  ((4.29), Biskinis Phd))  
 $M_y = 1.7613E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 1500.00  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.7095E+013$   
 $factor = 0.30$   
 $A_g = 202500.00$   
 Mean concrete strength:  $fc' = (fc'_jacket * Area\_jacket + fc'_core * Area\_core) / Area\_section = 28.98765$   
 $N = 7502.094$   
 $E_c * I_g = E_c\_jacket * I_g\_jacket + E_c\_core * I_g\_core = 9.0315E+013$

#### Calculation of Yielding Moment $M_y$

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

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$   
 $y_{\text{ten}} = 6.1806717\text{E-}006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/l_d)^{2/3}) = 374.3546$   
 $d = 407.00$   
 $y = 0.25591399$   
 $A = 0.01472387$   
 $B = 0.00818866$   
with  $p_t = 0.00430549$   
 $p_c = 0.00620943$   
 $p_v = 0.0021956$   
 $N = 7502.094$   
 $b = 450.00$   
 $\rho = 0.10565111$   
 $y_{\text{comp}} = 2.2127287\text{E-}005$   
with  $f_c^* (12.3, \text{ACI } 440)) = 34.40847$   
 $f_c = 33.00$   
 $f_l = 0.82797802$   
 $b = 450.00$   
 $h = 450.00$   
 $A_g = 202500.00$   
From (12.9), ACI 440:  $k_a = 0.54261599$   
 $g = p_t + p_c + p_v = 0.01461445$   
 $r_c = 40.00$   
 $A_e/A_c = 0.54261599$   
Effective FRP thickness,  $t_f = N L \cdot t \cdot \cos(b_1) = 1.016$   
effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.25471852$   
 $A = 0.01452517$   
 $B = 0.00807924$   
with  $E_s = 200000.00$

#### Calculation of ratio $l_b/l_d$

Lap Length:  $l_d/l_d, \text{min} = 0.42476573$

$l_b = 300.00$

$l_d = 706.2717$

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

$\rho = 1$   
 $d_b = 16.66667$   
Mean strength value of all re-bars:  $f_y = 524.4464$   
Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $c_b = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$   
where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$   
 $n = 12.00$

#### - Calculation of $\rho_p$ -

From table 10-8:  $\rho_p = 0.03861614$

with:

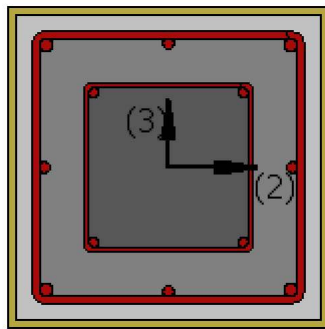
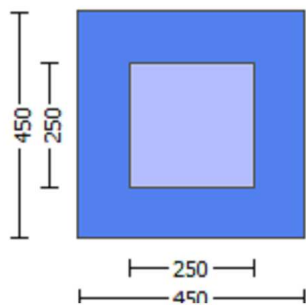
- Columns controlled by inadequate development or splicing along the clear height because  $l_b/l_d < 1$

shear control ratio  $V_{yE}/V_{Col0E} = 0.26068017$   
 $d = d_{external} = 407.00$   
 $s = s_{external} = 0.00$   
 $t = s_1 + s_2 + 2*tf/bw*(f_{fe}/f_s) = 0.00430549$   
 jacket:  $s_1 = A_{v1}*h_1/(s_1*Ag) = 0.00116355$   
 $A_{v1} = 157.0796$ , is the total area of all stirrups parallel to loading (shear) direction  
 $h_1 = 450.00$   
 $s_1 = 300.00$   
 core:  $s_2 = A_{v2}*h_2/(s_2*Ag) = 0.00103427$   
 $A_{v2} = 100.531$ , is the total area of all stirrups parallel to loading (shear) direction  
 $h_2 = 250.00$   
 $s_2 = 120.00$   
 The term  $2*tf/bw*(f_{fe}/f_s)$  is implemented to account for FRP contribution  
 where  $f = 2*tf/bw$  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.  
 For the normalisation  $f_s$  of jacket is used.  
 $NUD = 7502.094$   
 $Ag = 202500.00$   
 $f_{cE} = (f_{c,jacket}*Area_{jacket} + f_{c,core}*Area_{core})/section\_area = 28.98765$   
 $f_{yE} = (f_{y,ext\_Long\_Reinf}*Area_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf}*Area_{int\_Long\_Reinf})/Area_{Tot\_Long\_Rein} = 529.9972$   
 $f_{yE} = (f_{y,ext\_Trans\_Reinf}*s_1 + f_{y,int\_Trans\_Reinf}*s_2)/(s_1 + s_2) = 503.2682$   
 $\rho_l = Area_{Tot\_Long\_Rein}/(b*d) = 0.01461445$   
 $b = 450.00$   
 $d = 407.00$   
 $f_{cE} = 28.98765$

-----  
 End Of Calculation of Chord Rotation Capacity for element: column JC1 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 JC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

New material: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material: Steel Strength,  $f_s = f_{sm} = 555.56$

Existing Column

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

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

#####

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations, bi: 0.00°  
Number of layers, NL = 1  
Radius of rounding corners, R = 40.00

#### Stepwise Properties

EDGE -A-  
Bending Moment, Ma = -5.3402437E-010  
Shear Force, Va = 2.6378276E-013  
EDGE -B-  
Bending Moment, Mb = -2.5732098E-010  
Shear Force, Vb = -2.6378276E-013  
BOTH EDGES  
Axial Force, F = -7502.094  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension: Aslt = 0.00  
-Compression: Aslc = 2676.637  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension: Asl,ten = 1137.257  
-Compression: Asl,com = 1137.257  
-Middle: Asl,mid = 402.1239  
Mean Diameter of Tension Reinforcement, DbL,ten = 16.80

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity VR = \*Vn = 447100.239  
Vn ((10.3), ASCE 41-17) = knl\*VCol0 = 526000.281  
VCol = 526000.281  
knl = 1.00  
displacement\_ductility\_demand = 0.00

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

= 1 (normal-weight concrete)  
Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 22.22222, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)  
M/Vd = 2.00  
Mu = 2.5732098E-010  
Vu = 2.6378276E-013  
d = 0.8\*h = 360.00  
Nu = 7502.094  
Ag = 202500.00  
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 129852.496  
where:  
Vs1 = 62831.853 is calculated for jacket, with:  
d = 360.00  
Av = 157079.633  
fy = 500.00  
s = 300.00  
Vs1 is multiplied by Col1 = 0.66666667  
s/d = 0.83333333  
Vs2 = 67020.643 is calculated for core, with:  
d = 200.00  
Av = 100530.965  
fy = 400.00  
s = 120.00  
Vs2 is multiplied by Col2 = 1.00  
s/d = 0.60  
Vf ((11-3)-(11.4), ACI 440) = 214457.247  
f = 0.95, for fully-wrapped sections  
wf/sf = 1 (FRP strips adjacent to one another).  
In (11.3) sin + cos is replaced with (cot + cota)sina which is more a generalised expression,  
where is the angle of the crack direction (see KANEPE).  
This later relation, considered as a function Vf( , ), is implemented for every different fiber orientation ai,

as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
orientation 1:  $\theta_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$ , with:  
total thickness per orientation,  $t_{f1} = N_L * t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe} ((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
with  $f_u = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 507312.442$   
 $b_w = 450.00$

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

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

From analysis, chord rotation  $\theta = 1.4313203E-022$   
 $y = (M_y * L_s / 3) / E_{eff} = 0.00325023$  ((4.29), Biskinis Phd))  
 $M_y = 1.7613E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 1500.00  
From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} * E_c * I_g = 2.7095E+013$   
factor = 0.30  
 $A_g = 202500.00$   
Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$   
 $N = 7502.094$   
 $E_c * I_g = E_{c,\text{jacket}} * I_{g,\text{jacket}} + E_{c,\text{core}} * I_{g,\text{core}} = 9.0315E+013$

Calculation of Yielding Moment  $M_y$

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

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$   
 $y_{\text{ten}} = 6.1806717E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 374.3546$   
 $d = 407.00$   
 $y = 0.25591399$   
 $A = 0.01472387$   
 $B = 0.00818866$   
with  $p_t = 0.00620943$   
 $p_c = 0.00620943$   
 $p_v = 0.0021956$   
 $N = 7502.094$   
 $b = 450.00$   
 $\mu = 0.10565111$   
 $y_{\text{comp}} = 2.2127287E-005$   
with  $f_c^*$  (12.3, (ACI 440)) = 34.40847  
 $f_c = 33.00$   
 $f_l = 0.82797802$   
 $b = 450.00$   
 $h = 450.00$   
 $A_g = 202500.00$   
From (12.9), ACI 440:  $k_a = 0.54261599$   
 $g = p_t + p_c + p_v = 0.01461445$   
 $r_c = 40.00$   
 $A_e / A_c = 0.54261599$   
Effective FRP thickness,  $t_f = N_L * t * \text{Cos}(\theta_1) = 1.016$   
effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.25471852$   
 $A = 0.01452517$

B = 0.00807924  
with Es = 200000.00

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_d/l_{d,min} = 0.42476573$

$l_b = 300.00$

$l_d = 706.2717$

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

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 257.6106$

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

$s = \max(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

End Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (b)

## Calculation No. 16

column C1, Floor 1

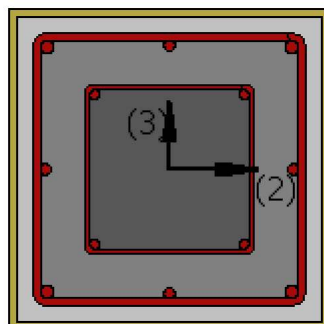
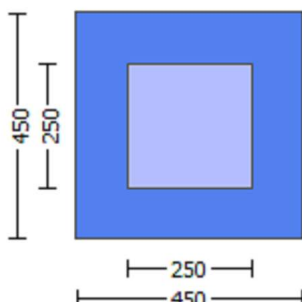
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\phi$ )

Edge: End

Local Axis: (3)





Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjrs

#### Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

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

#####

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 2.0531359E-031$

EDGE -B-

Shear Force,  $V_b = -2.0531359E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{slt} = 0.00$

-Compression:  $Asl_c = 2676.637$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $Asl_{ten} = 1137.257$   
 -Compression:  $Asl_{com} = 1137.257$   
 -Middle:  $Asl_{mid} = 402.1239$

Calculation of Shear Capacity ratio ,  $Ve/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $Ve = (M_{pr1} + M_{pr2})/l_n = 147952.607$   
 with

$M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 2.2193E+008$

$\mu_{u1+} = 2.2193E+008$ , 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

$\mu_{u1-} = 2.2193E+008$ , 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

$M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 2.2193E+008$

$\mu_{u2+} = 2.2193E+008$ , 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

$\mu_{u2-} = 2.2193E+008$ , 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:

$\mu_u = 1.9632832E-005$

$\mu_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$\alpha_0$  (5A.5, TBDY) = 0.002

Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \alpha_0) = 0.01393923$

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

From (5.4b), TBDY:  $\mu_u = 0.01393923$

$\mu_{ue}$  ((5.4c), TBDY) =  $\alpha_0 * \mu_u / f_{c,e} + \text{Min}(f_x, f_y) = 0.06811101$

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

$f_x = 0.06628267$

$\alpha_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$f_y = 0.06628267$

$\alpha_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$R = 40.00$

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

$f_u, f = 1055.00$

$E_f = 64828.00$

$u, f = 0.015$   
 $ase ((5.4d), TBDY) = (ase1 \cdot A_{ext} + ase2 \cdot A_{int}) / A_{sec} = 0.14546167$   
 $ase1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi2_1 = 608400.00$   
 $ase2 = \text{Max}(ase1, ase2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi2_2 = 234256.00$   
 $psh, \min \cdot F_{ywe} = \text{Min}(psh, x \cdot F_{ywe}, psh, y \cdot F_{ywe}) = 1.38262$   
 Expression ((5.4d), TBDY) for  $psh, \min \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh, x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / A_{sec} = 0.00116355$   
 $Ash1 = Astir_1 \cdot ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / A_{sec} = 0.00103427$   
 $Ash2 = Astir_2 \cdot ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

$psh, y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / A_{sec} = 0.00116355$   
 $Ash1 = Astir_1 \cdot ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / A_{sec} = 0.00103427$   
 $Ash2 = Astir_2 \cdot ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

$A_{sec} = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $fce = 33.00$   
 From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/ld = 0.33981258$   
 $su1 = 0.4 \cdot esu1_{\text{nominal}} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu1_{\text{nominal}} = 0.08$ ,  
 For calculation of  $esu1_{\text{nominal}}$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1 / 1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs1 = (fs, \text{jacket} \cdot A_{sl, \text{ten, jacket}} + fs, \text{core} \cdot A_{sl, \text{ten, core}}) / A_{sl, \text{ten}} = 399.8226$   
 with  $Es1 = (Es, \text{jacket} \cdot A_{sl, \text{ten, jacket}} + Es, \text{core} \cdot A_{sl, \text{ten, core}}) / A_{sl, \text{ten}} = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/lb, \min = 0.33981258$

$su_2 = 0.4 \cdot esu_{2\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2\_nominal} = 0.08$ ,  
 For calculation of  $esu_{2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 399.8226$   
 with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.00152175$   
 $sh_v = 0.0048696$   
 $ft_v = 507.2537$   
 $fy_v = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{u,min} = lb/ld = 0.33981258$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 422.7114$   
 with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.0752324$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.0752324$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.09371431$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.09371431$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.16791801$

$\mu_u = MR_c (4.14) = 2.2193E+008$

$u = su (4.1) = 1.9632832E-005$

-----  
 Calculation of ratio  $lb/ld$

-----  
 Lap Length:  $lb/ld = 0.33981258$

$lb = 300.00$

$ld = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} <= 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$

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

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

## Calculation of Mu1-

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

$$\mu = 1.9632832E-005$$

$$Mu = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu = \text{shear\_factor} * \text{Max}(\mu, \alpha) = 0.01393923$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01393923$$

$$\mu_e ((5.4c), TBDY) = \alpha * \mu_{sh,min} * f_{ywe} / f_{ce} + \text{Min}(\mu_x, \mu_y) = 0.06811101$$

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

$$\mu_x = 0.06628267$$

$$\alpha_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_p = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$\mu_y = 0.06628267$$

$$\alpha_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_p = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

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

$$\alpha_e ((5.4d), TBDY) = (\alpha_{e1} * A_{ext} + \alpha_{e2} * A_{int}) / A_{sec} = 0.14546167$$

$$\alpha_{e1} = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i,2,1} = 608400.00$$

$$\alpha_{e2} = \text{Max}(\alpha_{e1}, \alpha_{e2}) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i,2,2} = 234256.00$$

$$\mu_{sh,min} * f_{ywe} = \text{Min}(\mu_{sh,x} * f_{ywe}, \mu_{sh,y} * f_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $\mu_{sh,min} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\mu_{sh,x} * f_{ywe} = \mu_{sh1} * f_{ywe1} + \mu_{sh2} * f_{ywe2} = 1.38262$$

$$\mu_{ps1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$\mu_{ps2} (\text{internal}) = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h2 = 250.00$$

$$\begin{aligned} psh\_y * Fywe &= psh1 * Fywe1 + ps2 * Fywe2 = 1.38262 \\ ps1 \text{ (external)} &= (Ash1 * h1 / s1) / Asec = 0.00116355 \\ Ash1 &= Astir\_1 * ns\_1 = 157.0796 \\ \text{No stirups, } ns\_1 &= 2.00 \\ h1 &= 450.00 \\ ps2 \text{ (internal)} &= (Ash2 * h2 / s2) / Asec = 0.00103427 \\ Ash2 &= Astir\_2 * ns\_2 = 100.531 \\ \text{No stirups, } ns\_2 &= 2.00 \\ h2 &= 250.00 \end{aligned}$$

$$Asec = 202500.00$$

$$s1 = 300.00$$

$$s2 = 120.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

$$\text{From } ((5.A.5), \text{ TBDY}), \text{ TBDY: } cc = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$y1 = 0.00152175$$

$$sh1 = 0.0048696$$

$$ft1 = 479.7871$$

$$fy1 = 399.8226$$

$$su1 = 0.0066488$$

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

$$lo/lou, \min = lb/ld = 0.33981258$$

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

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs\_jacket * Asl, \text{ten, jacket} + fs\_core * Asl, \text{ten, core}) / Asl, \text{ten} = 399.8226$$

$$\text{with } Es1 = (Es\_jacket * Asl, \text{ten, jacket} + Es\_core * Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$$

$$y2 = 0.00152175$$

$$sh2 = 0.0048696$$

$$ft2 = 479.7871$$

$$fy2 = 399.8226$$

$$su2 = 0.0066488$$

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

$$lo/lou, \min = lb/lb, \min = 0.33981258$$

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

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2, ft2, fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs\_jacket * Asl, \text{com, jacket} + fs\_core * Asl, \text{com, core}) / Asl, \text{com} = 399.8226$$

$$\text{with } Es2 = (Es\_jacket * Asl, \text{com, jacket} + Es\_core * Asl, \text{com, core}) / Asl, \text{com} = 200000.00$$

$$yv = 0.00152175$$

$$shv = 0.0048696$$

$$ftv = 507.2537$$

$$fyv = 422.7114$$

$$suv = 0.0066488$$

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

$$lo/lou, \min = lb/ld = 0.33981258$$

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

From table 5A.1, TBDY: esuv\_nominal = 0.08,

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

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

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

```

with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438

```

and confined core properties:

```

b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
c = confinement factor = 1.10542
1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353

```

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

```

su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008
u = su (4.1) = 1.9632832E-005

```

Calculation of ratio lb/l<sub>d</sub>

Lap Length: lb/l<sub>d</sub> = 0.33981258

lb = 300.00

ld = 882.8396

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

= 1

db = 16.66667

Mean strength value of all re-bars: fy = 655.558

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 2.86234

Atr = Min(Atr\_x,Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y loxal axis

s = Max(s\_external,s\_internal) = 300.00

n = 12.00

Calculation of Mu2+

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

u = 1.9632832E-005

Mu = 2.2193E+008

with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.00124204

N = 7506.808

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01393923

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

From (5.4b), TBDY: cu = 0.01393923

$w_e ((5.4c), TBDY) = a_{se} \cdot \frac{sh_{min} \cdot f_{ywe}}{f_{ce}} + \min(f_x, f_y) = 0.06811101$   
where  $f = a_f \cdot p_f \cdot f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06628267$   
 $a_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$   
 $b_w = 450.00$   
effective stress from (A.35),  $f_{fe} = 881.8461$

$f_y = 0.06628267$   
 $a_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$   
 $b_w = 450.00$   
effective stress from (A.35),  $f_{fe} = 881.8461$

$R = 40.00$   
Effective FRP thickness,  $t_f = N_L \cdot t \cdot \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_f = 0.015$   
 $a_{se} ((5.4d), TBDY) = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int}) / A_{sec} = 0.14546167$   
 $a_{se1} = 0.12623274$   
 $b_{o,1} = 390.00$   
 $h_{o,1} = 390.00$   
 $b_{i2,1} = 608400.00$   
 $a_{se2} = \max(a_{se1}, a_{se2}) = 0.18853448$   
 $b_{o,2} = 242.00$   
 $h_{o,2} = 242.00$   
 $b_{i2,2} = 234256.00$

$p_{sh,min} \cdot f_{ywe} = \min(p_{sh,x} \cdot f_{ywe}, p_{sh,y} \cdot f_{ywe}) = 1.38262$   
Expression ((5.4d), TBDY) for  $p_{sh,min} \cdot f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \cdot f_{ywe} = p_{sh1} \cdot f_{ywe1} + p_{sh2} \cdot f_{ywe2} = 1.38262$   
 $p_{s1} \text{ (external)} = (A_{sh1} \cdot h_1 / s_1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir,1} \cdot n_{s,1} = 157.0796$   
No stirrups,  $n_{s,1} = 2.00$   
 $h_1 = 450.00$   
 $p_{s2} \text{ (internal)} = (A_{sh2} \cdot h_2 / s_2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir,2} \cdot n_{s,2} = 100.531$   
No stirrups,  $n_{s,2} = 2.00$   
 $h_2 = 250.00$

$p_{sh,y} \cdot f_{ywe} = p_{sh1} \cdot f_{ywe1} + p_{sh2} \cdot f_{ywe2} = 1.38262$   
 $p_{s1} \text{ (external)} = (A_{sh1} \cdot h_1 / s_1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir,1} \cdot n_{s,1} = 157.0796$   
No stirrups,  $n_{s,1} = 2.00$   
 $h_1 = 450.00$   
 $p_{s2} \text{ (internal)} = (A_{sh2} \cdot h_2 / s_2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir,2} \cdot n_{s,2} = 100.531$   
No stirrups,  $n_{s,2} = 2.00$   
 $h_2 = 250.00$

$A_{sec} = 202500.00$   
 $s_1 = 300.00$   
 $s_2 = 120.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$   
From ((5.A5), TBDY), TBDY:  $c_c = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $y_1 = 0.00152175$   
 $sh_1 = 0.0048696$



```

ft1 = 479.7871
fy1 = 399.8226
su1 = 0.0066488
    using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.33981258
    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, ASCE 41-17.
    with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 399.8226
    with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00152175
sh2 = 0.0048696
ft2 = 479.7871
fy2 = 399.8226
su2 = 0.0066488
    using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.33981258
    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, ASCE 41-17.
    with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226
    with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00152175
shv = 0.0048696
ftv = 507.2537
fyv = 422.7114
suv = 0.0066488
    using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.33981258
    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, ASCE 41-17.
    with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
    c = confinement factor = 1.10542
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
    2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
    v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008

```

$$u = su(4.1) = 1.9632832E-005$$

Calculation of ratio lb/d

Lap Length: lb/d = 0.33981258

lb = 300.00

ld = 882.8396

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

= 1

db = 16.66667

Mean strength value of all re-bars: fy = 655.558

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 2.86234

Atr = Min(Atr\_x, Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y loxal axis

s = Max(s\_external, s\_internal) = 300.00

n = 12.00

Calculation of Mu2-

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

$$u = 1.9632832E-005$$

$$Mu = 2.2193E+008$$

with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.00124204

N = 7506.808

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu:  $cu^* = shear\_factor \cdot \max(cu, cc) = 0.01393923$

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

From (5.4b), TBDY:  $cu = 0.01393923$

we ((5.4c), TBDY) =  $ase \cdot sh_{min} \cdot fy_{we} / fce + \min(fx, fy) = 0.06811101$

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

fx = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00451556$

bw = 450.00

effective stress from (A.35),  $ffe = 881.8461$

fy = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00451556$

bw = 450.00

effective stress from (A.35),  $ffe = 881.8461$

R = 40.00

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

fu,f = 1055.00

$E_f = 64828.00$   
 $u, f = 0.015$   
 $ase((5.4d), TBDY) = (ase1 \cdot A_{ext} + ase2 \cdot A_{int}) / A_{sec} = 0.14546167$   
 $ase1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi2_1 = 608400.00$   
 $ase2 = \text{Max}(ase1, ase2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi2_2 = 234256.00$   
 $psh, \min \cdot F_{ywe} = \text{Min}(psh, x \cdot F_{ywe}, psh, y \cdot F_{ywe}) = 1.38262$   
 Expression ((5.4d), TBDY) for  $psh, \min \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh, x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / A_{sec} = 0.00116355$   
 $Ash1 = Astir_1 \cdot ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / A_{sec} = 0.00103427$   
 $Ash2 = Astir_2 \cdot ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

$psh, y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / A_{sec} = 0.00116355$   
 $Ash1 = Astir_1 \cdot ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / A_{sec} = 0.00103427$   
 $Ash2 = Astir_2 \cdot ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

$A_{sec} = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $f_{ce} = 33.00$   
 From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $lo/lou, \min = lb/ld = 0.33981258$   
 $su1 = 0.4 \cdot esu1_{nominal}((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,  
 For calculation of  $esu1_{nominal}$  and  $y1, sh1, ft1, fy1$ , 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, ASCE 41-17.  
 with  $fs1 = (fs, \text{jacket} \cdot A_{sl, \text{ten, jacket}} + fs, \text{core} \cdot A_{sl, \text{ten, core}}) / A_{sl, \text{ten}} = 399.8226$   
 with  $Es1 = (Es, \text{jacket} \cdot A_{sl, \text{ten, jacket}} + Es, \text{core} \cdot A_{sl, \text{ten, core}}) / A_{sl, \text{ten}} = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.33981258$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 399.8226$   
 with  $Es_2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$   
 $y_v = 0.00152175$   
 $sh_v = 0.0048696$   
 $ft_v = 507.2537$   
 $fy_v = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.33981258$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsv = fs_v/1.2$ , 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, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 422.7114$   
 with  $Es_v = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / f_c) = 0.0752324$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / f_c) = 0.0752324$   
 $v = A_{sl,mid} / (b * d) * (fs_v / f_c) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / f_c) = 0.09371431$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / f_c) = 0.09371431$   
 $v = A_{sl,mid} / (b * d) * (fs_v / f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

$su (4.9) = 0.16791801$

$\mu_u = M_{Rc} (4.14) = 2.2193E+008$

$u = su (4.1) = 1.9632832E-005$

-----  
 Calculation of ratio  $l_b/l_d$   
 -----

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = Min(A_{tr,x}, A_{tr,y}) = 257.6106$

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

$s = Max(s_{external}, s_{internal}) = 300.00$

$$n = 12.00$$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$

Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$V_{Col0} = 567563.724$

$knl = 1$  (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)

Mean concrete strength:  $f_c' = (f_c'_{jacket} * \text{Area}_{jacket} + f_c'_{core} * \text{Area}_{core}) / \text{Area}_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 1.4404090E-011$

$\nu_u = 2.0531359E-031$

$d = 0.8 * h = 360.00$

$N_u = 7506.808$

$A_g = 202500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 300.00$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$s/d = 0.83333333$

$V_{s2} = 74466.637$  is calculated for core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 120.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.60$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 214457.247$

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 407.00

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$

$b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$

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

$V_{Col0} = 567563.724$

$knl = 1$  (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)  
Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.4404090E-011$   
 $\mu_v = 2.0531359E-031$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f ((11-3)-(11.4), ACI 440) = 214457.247$   
 $f = 0.95$ , 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,  $t_{f1} = NL \cdot t / NoDir = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
with  $f_u = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $b_w = 450.00$

-----  
End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At local axis: 3  
-----

-----  
Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjrs

Constant Properties

-----  
Knowledge Factor,  $\phi = 0.85$   
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
Concrete Elasticity,  $E_c = 21019.039$   
Steel Elasticity,  $E_s = 200000.00$   
#####  
Note: Especially for the calculation of moment strengths,  
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
Jacket  
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
Existing Column  
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$   
#####  
External Height,  $H = 450.00$   
External Width,  $W = 450.00$   
Internal Height,  $H = 250.00$   
Internal Width,  $W = 250.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.10542  
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $\epsilon_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i: 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = -2.7162834E-031$   
EDGE -B-  
Shear Force,  $V_b = 2.7162834E-031$   
BOTH EDGES  
Axial Force,  $F = -7506.808$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{slt} = 0.00$   
-Compression:  $A_{slc} = 2676.637$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten} = 1137.257$   
-Compression:  $A_{sl,com} = 1137.257$   
-Middle:  $A_{sl,mid} = 402.1239$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$   
with  
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.2193E+008$   
 $M_{u1+} = 2.2193E+008$ , 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  
 $M_{u1-} = 2.2193E+008$ , 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  
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.2193E+008$

Mu2+ = 2.2193E+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

Mu2- = 2.2193E+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 Mu1+  
-----

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

$$\phi_u = 1.9632832E-005$$

$$M_u = 2.2193E+008$$

-----  
with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_{cu}: \phi_{cu}^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{co}) = 0.01393923$$

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

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01393923$$

$$\phi_{we} \text{ ((5.4c), TBDY)} = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.06811101$$

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

$$\phi_{fx} = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_{pf} = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$\phi_{fy} = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_{pf} = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(\theta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$a_{se1} = 0.12623274$$

$$b_{o\_1} = 390.00$$

$$h_{o\_1} = 390.00$$

$$b_{i2\_1} = 608400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$$

$$b_{o\_2} = 242.00$$

$$h_{o\_2} = 242.00$$

$$b_{i2\_2} = 234256.00$$

$$\phi_{sh, \min} * f_{ywe} = \text{Min}(\phi_{sh, x} * f_{ywe}, \phi_{sh, y} * f_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $\phi_{sh, \min} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\phi_{sh, x} * f_{ywe} = \phi_{sh1} * f_{ywe1} + \phi_{sh2} * f_{ywe2} = 1.38262$$

$$\phi_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir\_1} * n_{s\_1} = 157.0796$$

$$\text{No stirrups, } n_{s\_1} = 2.00$$

$$h_1 = 450.00$$



$$ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$$

$$Ash2 = Astir\_2 \cdot ns\_2 = 100.531$$

$$\text{No stirups, } ns\_2 = 2.00$$

$$h2 = 250.00$$

$$psh\_y \cdot Fywe = psh1 \cdot Fywe1 + ps2 \cdot Fywe2 = 1.38262$$

$$ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / Asec = 0.00116355$$

$$Ash1 = Astir\_1 \cdot ns\_1 = 157.0796$$

$$\text{No stirups, } ns\_1 = 2.00$$

$$h1 = 450.00$$

$$ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$$

$$Ash2 = Astir\_2 \cdot ns\_2 = 100.531$$

$$\text{No stirups, } ns\_2 = 2.00$$

$$h2 = 250.00$$

$$Asec = 202500.00$$

$$s1 = 300.00$$

$$s2 = 120.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

$$\text{From } ((5.A.5), \text{ TBDY}), \text{ TBDY: } cc = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$y1 = 0.00152175$$

$$sh1 = 0.0048696$$

$$ft1 = 479.7871$$

$$fy1 = 399.8226$$

$$su1 = 0.0066488$$

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

$$lo/lou, \min = lb/ld = 0.33981258$$

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

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs\_jacket \cdot Asl, \text{ten, jacket} + fs\_core \cdot Asl, \text{ten, core}) / Asl, \text{ten} = 399.8226$$

$$\text{with } Es1 = (Es\_jacket \cdot Asl, \text{ten, jacket} + Es\_core \cdot Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$$

$$y2 = 0.00152175$$

$$sh2 = 0.0048696$$

$$ft2 = 479.7871$$

$$fy2 = 399.8226$$

$$su2 = 0.0066488$$

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

$$lo/lou, \min = lb/lb, \min = 0.33981258$$

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

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2, ft2, fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs\_jacket \cdot Asl, \text{com, jacket} + fs\_core \cdot Asl, \text{com, core}) / Asl, \text{com} = 399.8226$$

$$\text{with } Es2 = (Es\_jacket \cdot Asl, \text{com, jacket} + Es\_core \cdot Asl, \text{com, core}) / Asl, \text{com} = 200000.00$$

$$yv = 0.00152175$$

$$shv = 0.0048696$$

$$ftv = 507.2537$$

$$fyv = 422.7114$$

$$suv = 0.0066488$$

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

$$lo/lou, \min = lb/ld = 0.33981258$$

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

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, ASCE 41-17.

with  $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 422.7114$

with  $Esv = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$

$1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.0752324$

$2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.0752324$

$v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$fcc$  (5A.2, TBDY) = 36.47874

$cc$  (5A.5, TBDY) = 0.00305417

$c$  = confinement factor = 1.10542

$1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.09371431$

$2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.09371431$

$v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs_{y2}$  - LHS eq.(4.5) is satisfied

--->

$su$  (4.9) = 0.16791801

$Mu = MRc$  (4.14) = 2.2193E+008

$u = su$  (4.1) = 1.9632832E-005

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.33981258$

$lb = 300.00$

$ld = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$Ktr = 2.86234$

$Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$

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

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

Calculation of  $Mu1$ -

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

$u = 1.9632832E-005$

$Mu = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$fc = 33.00$

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

Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$

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

From (5.4b), TBDY:  $c_u = 0.01393923$

$w_e$  ((5.4c), TBDY) =  $a_{se} * \text{sh\_min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$

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

$f_x = 0.06628267$

$a_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$f_y = 0.06628267$

$a_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$R = 40.00$

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) =  $(a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.14546167$

$a_{se1} = 0.12623274$

$bo\_1 = 390.00$

$ho\_1 = 390.00$

$bi2\_1 = 608400.00$

$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$

$bo\_2 = 242.00$

$ho\_2 = 242.00$

$bi2\_2 = 234256.00$

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 1.38262$

Expression ((5.4d), TBDY) for  $p_{sh,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 1.38262$

$ps1$  (external) =  $(A_{sh1} * h_1/s_1)/A_{sec} = 0.00116355$

$A_{sh1} = A_{stir\_1} * ns\_1 = 157.0796$

No stirrups,  $ns\_1 = 2.00$

$h_1 = 450.00$

$ps2$  (internal) =  $(A_{sh2} * h_2/s_2)/A_{sec} = 0.00103427$

$A_{sh2} = A_{stir\_2} * ns\_2 = 100.531$

No stirrups,  $ns\_2 = 2.00$

$h_2 = 250.00$

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 1.38262$

$ps1$  (external) =  $(A_{sh1} * h_1/s_1)/A_{sec} = 0.00116355$

$A_{sh1} = A_{stir\_1} * ns\_1 = 157.0796$

No stirrups,  $ns\_1 = 2.00$

$h_1 = 450.00$

$ps2$  (internal) =  $(A_{sh2} * h_2/s_2)/A_{sec} = 0.00103427$

$A_{sh2} = A_{stir\_2} * ns\_2 = 100.531$

No stirrups,  $ns\_2 = 2.00$

$h_2 = 250.00$

$A_{sec} = 202500.00$

$s_1 = 300.00$

$s_2 = 120.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$

```

c = confinement factor = 1.10542
y1 = 0.00152175
sh1 = 0.0048696
ft1 = 479.7871
fy1 = 399.8226
su1 = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258
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, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 399.8226
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00152175
sh2 = 0.0048696
ft2 = 479.7871
fy2 = 399.8226
su2 = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.33981258
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, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00152175
shv = 0.0048696
ftv = 507.2537
fyv = 422.7114
suv = 0.0066488
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.33981258
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, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324
2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324
v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 36.47874
cc (5A.5, TBDY) = 0.00305417
c = confinement factor = 1.10542
1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431
2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431
v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied

```

```

--->
su (4.9) = 0.16791801
Mu = MRc (4.14) = 2.2193E+008
u = su (4.1) = 1.9632832E-005
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.33981258
lb = 300.00
ld = 882.8396
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.98765, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.86234
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 300.00
n = 12.00
-----
-----
-----

Calculation of Mu2+
-----
-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.9632832E-005
Mu = 2.2193E+008
-----

with full section properties:
b = 450.00
d = 407.00
d' = 43.00
v = 0.00124204
N = 7506.808
fc = 33.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01393923
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01393923
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.06811101
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
-----
fx = 0.06628267
af = 0.54930041
b = 450.00
h = 450.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556
bw = 450.00
effective stress from (A.35), ff,e = 881.8461
-----
fy = 0.06628267
af = 0.54930041
b = 450.00
h = 450.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556
bw = 450.00
effective stress from (A.35), ff,e = 881.8461
-----

```

$R = 40.00$   
 Effective FRP thickness,  $t_f = N L * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.14546167$   
 $ase_1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi_2_1 = 608400.00$   
 $ase_2 = \max(ase_1, ase_2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi_2_2 = 234256.00$   
 $psh_{,min} * F_{ywe} = \min(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 1.38262$   
 Expression ((5.4d), TBDY) for  $psh_{,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 1.38262$   
 $ps_1 \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir\_1} * ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2 \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir\_2} * ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

$psh_{,y} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 1.38262$   
 $ps_1 \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir\_1} * ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2 \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir\_2} * ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

$A_{sec} = 202500.00$   
 $s_1 = 300.00$   
 $s_2 = 120.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y_1 = 0.00152175$   
 $sh_1 = 0.0048696$   
 $ft_1 = 479.7871$   
 $fy_1 = 399.8226$   
 $su_1 = 0.0066488$

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

$lo/lo_{u,min} = l_b / l_d = 0.33981258$   
 $su_1 = 0.4 * esu_{1,nominal}((5.5), TBDY) = 0.032$

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, ASCE 41-17.

with  $fs_1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 399.8226$

with  $Es_1 = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.00152175$   
 $sh_2 = 0.0048696$   
 $ft_2 = 479.7871$   
 $fy_2 = 399.8226$   
 $su_2 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.33981258$   
 $su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 399.8226$   
with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.00152175$   
 $sh_v = 0.0048696$   
 $ft_v = 507.2537$   
 $fy_v = 422.7114$   
 $suv = 0.0066488$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.33981258$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 422.7114$   
with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.0752324$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.0752324$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.09371431$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.09371431$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.03503353$

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

--->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$$

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$$

$$n = 12.00$$

Calculation of  $\mu_2$ -

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

$$\mu = 1.9632832\text{E-}005$$

$$\mu_2 = 2.2193\text{E+}008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$\alpha_2 (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu_2: \mu_2^* = \text{shear\_factor} * \text{Max}(\mu_2, \mu_2^*) = 0.01393923$$

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

$$\text{From (5.4b), TBDY: } \mu_2 = 0.01393923$$

$$\mu_2 ((5.4c), \text{TBDY}) = \alpha_2 * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(\mu_{2x}, \mu_{2y}) = 0.06811101$$

where  $\mu_2 = \alpha_2 * \rho_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\mu_{2x} = 0.06628267$$

$$\alpha_2 = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$\mu_{2y} = 0.06628267$$

$$\alpha_2 = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(\theta_1) = 1.016$$

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

$$E_f = 64828.00$$

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

$$\alpha_2 ((5.4d), \text{TBDY}) = (\alpha_1 * A_{\text{ext}} + \alpha_2 * A_{\text{int}}) / A_{\text{sec}} = 0.14546167$$

$$\alpha_1 = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i2,1} = 608400.00$$

$$\alpha_2 = \text{Max}(\alpha_1, \alpha_2) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i2,2} = 234256.00$$

$$\text{psh}_{\text{min}} * f_{ywe} = \text{Min}(\text{psh}_x * f_{ywe}, \text{psh}_y * f_{ywe}) = 1.38262$$

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

$$\text{psh}_x * f_{ywe} = \text{psh}_1 * f_{ywe1} + \text{ps}_2 * f_{ywe2} = 1.38262$$

$$\text{ps}_1 (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{\text{sec}} = 0.00116355$$

$$A_{sh1} = A_{\text{stir}_1} * n_{s1} = 157.0796$$

$$\text{No stirrups, } n_{s1} = 2.00$$



$h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 \cdot ns\_2 = 100.531$   
 No stirups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$psh\_y \cdot Fywe = psh1 \cdot Fywe1 + ps2 \cdot Fywe2 = 1.38262$   
 $ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / Asec = 0.00116355$   
 $Ash1 = Astir\_1 \cdot ns\_1 = 157.0796$   
 No stirups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$   
 $Ash2 = Astir\_2 \cdot ns\_2 = 100.531$   
 No stirups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$Asec = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$

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

$lo/lou, min = lb/ld = 0.33981258$

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

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

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs\_jacket \cdot Asl, ten, jacket + fs\_core \cdot Asl, ten, core) / Asl, ten = 399.8226$

with  $Es1 = (Es\_jacket \cdot Asl, ten, jacket + Es\_core \cdot Asl, ten, core) / Asl, ten = 200000.00$

$y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$

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

$lo/lou, min = lb/lb, min = 0.33981258$

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

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs\_jacket \cdot Asl, com, jacket + fs\_core \cdot Asl, com, core) / Asl, com = 399.8226$

with  $Es2 = (Es\_jacket \cdot Asl, com, jacket + Es\_core \cdot Asl, com, core) / Asl, com = 200000.00$

$yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$

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

$lo/lou, min = lb/ld = 0.33981258$

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

From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,

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

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 422.7114$

with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0752324$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0752324$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$f_{cc}$  (5A.2, TBDY) = 36.47874

$cc$  (5A.5, TBDY) = 0.00305417

$c$  = confinement factor = 1.10542

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09371431$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09371431$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su$  (4.9) = 0.16791801

$Mu = MR_c$  (4.14) = 2.2193E+008

$u = su$  (4.1) = 1.9632832E-005

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

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

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$

Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$V_{Col0} = 567563.724$

$k_{nl} = 1$  (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)

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu = 1.0463738E-012$   
 $\nu = 2.7162834E-031$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f ((11-3)-(11.4), ACI 440) = 214457.247$   
 $f = 0.95$ , 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:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = k_n l \cdot V_{Col0}$   
 $V_{Col0} = 567563.724$   
 $k_n l = 1$  (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)  
 Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu = 1.0463738E-012$   
 $\nu = 2.7162834E-031$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:

$d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 Vs2 is multiplied by Col2 = 1.00  
 $s/d = 0.60$   
 $V_f((11-3)-(11.4), \text{ACI 440}) = 214457.247$   
 $f = 0.95$ , 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:  $\theta_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L * t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $b_w = 450.00$

-----  
 -----  
 End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
 At local axis: 2

-----  
 Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1  
 At local axis: 3  
 Integration Section: (b)  
 Section Type: rcjrs

#### Constant Properties

-----  
 Knowledge Factor,  $\phi = 0.85$   
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.  
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
 Concrete Elasticity,  $E_c = 21019.039$   
 Steel Elasticity,  $E_s = 200000.00$   
 External Height,  $H = 450.00$   
 External Width,  $W = 450.00$   
 Internal Height,  $H = 250.00$   
 Internal Width,  $W = 250.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Primary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_b = 300.00$   
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)

Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $e_{fu} = 0.01$   
Number of directions,  $NoDir = 1$   
Fiber orientations,  $bi = 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = 0.09202348$   
Shear Force,  $V_2 = 11781.223$   
Shear Force,  $V_3 = -2.6378276E-013$   
Axial Force,  $F = -7502.094$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
- Tension:  $As_t = 0.00$   
- Compression:  $As_c = 2676.637$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
- Tension:  $As_{ten} = 1137.257$   
- Compression:  $As_{com} = 1137.257$   
- Middle:  $As_{mid} = 402.1239$   
Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
- Tension:  $As_{ten,jacket} = 829.3805$   
- Compression:  $As_{com,jacket} = 829.3805$   
- Middle:  $As_{mid,jacket} = 402.1239$   
Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
- Tension:  $As_{ten,core} = 307.8761$   
- Compression:  $As_{com,core} = 307.8761$   
- Middle:  $As_{mid,core} = 0.00$   
Mean Diameter of Tension Reinforcement,  $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = u = 0.03337626$   
 $u = y + p = 0.03926619$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00065005$  ((4.29), Biskinis Phd))  
 $M_y = 1.7613E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 300.00  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.7095E+013$   
factor = 0.30  
 $A_g = 202500.00$   
Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.98765$   
 $N = 7502.094$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 9.0315E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 6.1806717E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 374.3546$   
 $d = 407.00$   
 $y = 0.25591399$   
 $A = 0.01472387$   
 $B = 0.00818866$   
with  $pt = 0.00430549$   
 $pc = 0.00620943$

$p_v = 0.0021956$   
 $N = 7502.094$   
 $b = 450.00$   
 $" = 0.10565111$   
 $y_{comp} = 2.2127287E-005$   
 with  $f_c^* (12.3, (ACI 440)) = 34.40847$   
 $f_c = 33.00$   
 $f_l = 0.82797802$   
 $b = 450.00$   
 $h = 450.00$   
 $A_g = 202500.00$   
 From (12.9), ACI 440:  $k_a = 0.54261599$   
 $g = p_t + p_c + p_v = 0.01461445$   
 $r_c = 40.00$   
 $A_e/A_c = 0.54261599$   
 Effective FRP thickness,  $t_f = N L^* t^* \cos(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.25471852$   
 $A = 0.01452517$   
 $B = 0.00807924$   
 with  $E_s = 200000.00$

#### Calculation of ratio $l_b/l_d$

Lap Length:  $l_d/l_{d,min} = 0.42476573$

$l_b = 300.00$

$l_d = 706.2717$

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

$= 1$

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$

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

$s = \max(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

#### - Calculation of $p$ -

From table 10-8:  $p = 0.03861614$

with:

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

shear control ratio  $V_y E / V_{col} E = 0.26068017$

$d = d_{external} = 407.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00430549$

jacket:  $s_1 = A_{v1} \cdot h_1 / (s_1 \cdot A_g) = 0.00116355$

$A_{v1} = 157.0796$ , is the total area of all stirrups parallel to loading (shear) direction

$h_1 = 450.00$

$s_1 = 300.00$

core:  $s_2 = A_{v2} \cdot h_2 / (s_2 \cdot A_g) = 0.00103427$

$A_{v2} = 100.531$ , is the total area of all stirrups parallel to loading (shear) direction

$h_2 = 250.00$

$s_2 = 120.00$

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.

For the normalisation  $f_s$  of jacket is used.

$$N_{UD} = 7502.094$$

$$A_g = 202500.00$$

$$f_{cE} = (f_{c\_jacket} \cdot Area\_jacket + f_{c\_core} \cdot Area\_core) / section\_area = 28.98765$$

$$f_{yE} = (f_{y\_ext\_Long\_Reinf} \cdot Area\_ext\_Long\_Reinf + f_{y\_int\_Long\_Reinf} \cdot Area\_int\_Long\_Reinf) / Area\_Tot\_Long\_Rein = 529.9972$$

$$f_{yE} = (f_{y\_ext\_Trans\_Reinf} \cdot s_1 + f_{y\_int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 503.2682$$

$$\rho_l = Area\_Tot\_Long\_Rein / (b \cdot d) = 0.01461445$$

$$b = 450.00$$

$$d = 407.00$$

$$f_{cE} = 28.98765$$

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End Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (b)

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