

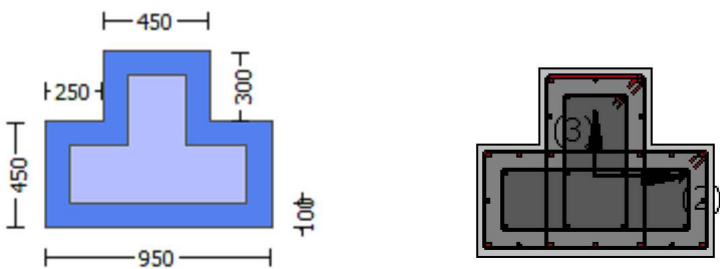
# Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

## Calculation No. 1

- column C1, Floor 1
- Limit State: Operational Level (data interpolation between analysis steps 1 and 2)
- Analysis: Uniform +X
- Check: Shear capacity VRd
- Edge: Start
- Local Axis: (2)



- Start Of Calculation of Shear Capacity for element: column JTC1 of floor 1
- At local axis: 2
- Integration Section: (a)
- Section Type: rcjtcs
- Constant Properties
- Knowledge Factor,  $\gamma = 1.00$
- 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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$
- New material of Secondary 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  
New material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
Concrete Elasticity,  $E_c = 26999.444$   
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  
New material: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material: Steel Strength,  $f_s = f_{sm} = 555.56$   
#####  
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 450.00$   
Max Width,  $W_{max} = 950.00$   
Min Width,  $W_{min} = 450.00$   
Eccentricity,  $Ecc = 250.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Secondary Member  
Smooth Bars  
Ductile Steel  
With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = l_b = 300.00$   
No FRP Wrapping

#### Stepwise Properties

EDGE -A-  
Bending Moment,  $M_a = -2.4234E+007$   
Shear Force,  $V_a = -8018.608$   
EDGE -B-  
Bending Moment,  $M_b = 173791.562$   
Shear Force,  $V_b = 8018.608$   
BOTH EDGES  
Axial Force,  $F = -21552.589$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten} = 1539.38$   
-Compression:  $As_{l,com} = 1539.38$   
-Middle:  $As_{l,mid} = 3612.832$   
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.57143$

New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 1.2174E+006$   
 $V_n$  ((10.3), ASCE 41-17) =  $kn_l \cdot V_{CoI0} = 1.2174E+006$   
 $V_{CoI} = 1.2174E+006$   
 $kn_l = 1.00$   
displacement\_ductility\_demand = 0.02755298

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:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 25.00$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 3.97662$

$\mu_u = 2.4234E+007$

$V_u = 8018.608$

$d = 0.8 \cdot h = 760.00$

$N_u = 21552.589$

$A_g = 427500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 1.0003E+006$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 879645.943$

$V_{sj1} = 282743.339$  is calculated for section web jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{sj1}$  is multiplied by  $Col,j1 = 1.00$

$s/d = 0.27777778$

$V_{sj2} = 596902.604$  is calculated for section flange jacket, with:

$d = 760.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{sj2}$  is multiplied by  $Col,j2 = 1.00$

$s/d = 0.13157895$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 120637.158$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 500.00$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$

$s/d = 1.25$

$V_{s,c2} = 120637.158$  is calculated for section flange core, with:

$d = 600.00$

$A_v = 100530.965$

$f_y = 500.00$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$

$s/d = 0.41666667$

$V_f ((11-3)-(11.4), ACI 440) = 0.00$

From (11-11), ACI 440:  $V_s + V_f \leq 1.1360E+006$

$bw = 450.00$

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  $\theta = 5.1815369E-005$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00188057$  ((4.29), Biskinis Phd)

$M_y = 5.2059E+008$

$L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 3022.232

From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 2.7887E+014$

factor = 0.30

$A_g = 562500.00$

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 33.00$

$N = 21552.589$

$E_c \cdot I_g = E_c \cdot I_{g,jacket} + E_c \cdot I_{g,core} = 9.2958E+014$

Calculation of Yielding Moment  $M_y$

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

```

y = Min( y_ten, y_com)
y_ten = 1.7803416E-006
with ((10.1), ASCE 41-17) fy = Min(fy, 1.25*fy*(lb/ld)^ 2/3) = 239.4634
d = 907.00
y = 0.25852163
A = 0.01661545
B = 0.00880662
with pt = 0.0037716
pc = 0.0037716
pv = 0.00885172
N = 21552.589
b = 450.00
" = 0.04740904
y_comp = 9.4779300E-006
with fc = 33.00
Ec = 26999.444
y = 0.25592389
A = 0.01627492
B = 0.0085861
with Es = 200000.00

```

Calculation of ratio lb/ld

Lap Length: ld/ld,min = 0.20248702

lb = 300.00

ld = 1481.576

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

ld,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (10.3.5, ASCE 41-17)

= 1

db = 16.66667

Mean strength value of all re-bars: fy = 555.56

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 33.00, 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 = 1.37392

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) = 250.00

n = 30.00

End Of Calculation of Shear Capacity for element: column JTC1 of floor 1

At local axis: 2

Integration Section: (a)

## Calculation No. 2

column C1, Floor 1

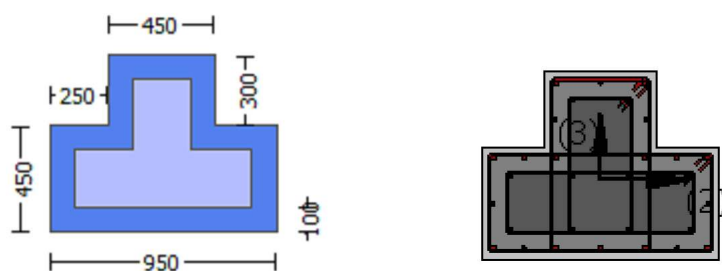
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $E_{cc} = 250.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.22443

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel  
With Detailing for Earthquake Resistance (including stirrups closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = 300.00$   
No FRP Wrapping

#### Stepwise Properties

At local axis: 3  
EDGE -A-  
Shear Force,  $V_a = 4.6187021E-017$   
EDGE -B-  
Shear Force,  $V_b = -4.6187021E-017$   
BOTH EDGES  
Axial Force,  $F = -20792.022$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{ten} = 1539.38$   
-Compression:  $As_{com} = 2475.575$   
-Middle:  $As_{mid} = 2676.637$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.29138786$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 386950.491$   
with  
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 5.8043E+008$   
 $M_{u1+} = 3.2937E+008$ , 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  
 $M_{u1-} = 5.8043E+008$ , 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  
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 5.8043E+008$   
 $M_{u2+} = 3.2937E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination  
 $M_{u2-} = 5.8043E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

#### Calculation of $M_{u1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\phi_u = 5.2477290E-006$   
 $M_u = 3.2937E+008$

with full section properties:

$b = 950.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00093808$   
 $N = 20792.022$   
 $f_c = 33.00$   
 $\phi_c (5A.5, \text{TBDY}) = 0.002$   
Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01151713$   
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY:  $\phi_u = 0.01151713$   
 $\phi_{we} (5.4c) = 0.04017143$   
 $\phi_{ase} ((5.4d), \text{TBDY}) = (\phi_{ase1} * A_{ext} + \phi_{ase2} * A_{int}) / A_{sec} = 0.53375773$   
 $\phi_{ase1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$   
The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$

$psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$

$psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 ((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00424426$

$c = \text{confinement factor} = 1.22443$

$y1 = 0.00092863$

$sh1 = 0.00297161$

$ft1 = 309.5449$

$fy1 = 257.9541$

$su1 = 0.00297161$

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

$l_o/l_{ou,min} = l_b/l_d = 0.16198962$

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

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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 257.9541$

with  $Es1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y2 = 0.00092863$

$sh2 = 0.00297161$

$ft2 = 309.5449$

$fy2 = 257.9541$

```

su2 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0179156
2 = Asl,com/(b*d)*(fs2/fc) = 0.02881122
v = Asl,mid/(b*d)*(fsv/fc) = 0.03115121

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and confined core properties:

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b = 890.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.01997081
2 = Asl,com/(b*d)*(fs2/fc) = 0.03211633
v = Asl,mid/(b*d)*(fsv/fc) = 0.03472476

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

```

---->
v < vs,y2 - LHS eq.(4.5) is satisfied
---->
su (4.9) = 0.19905879
Mu = MRc (4.14) = 3.2937E+008
u = su (4.1) = 5.2477290E-006

```

Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.16198962
lb = 300.00
lb = 1851.971
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
lb,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, but fc'^0.5 <= 8.3
MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00

```



$cb = 25.00$   
 $Ktr = 1.37392$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$   
 $n = 30.00$

Calculation of  $Mu1$ -

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

$u = 5.5327066E-006$   
 $Mu = 5.8043E+008$

with full section properties:

$b = 450.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00198039$   
 $N = 20792.022$   
 $fc = 33.00$   
 $\alpha (5A.5, TBDY) = 0.002$

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01151713$

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

From (5.4b), TBDY:  $\phi_u = 0.01151713$

we (5.4c) = 0.04017143

$\alpha_{se} ((5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.53375773$

$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\alpha_{se2} (>= \alpha_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$

$psh_x * F_{ywe} = psh1 * F_{ywe1} + psh2 * F_{ywe2} = 2.48363$

$psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 ((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + psh2 * F_{ywe2} = 2.97078$

$psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

Astir1 (stirrups area) = 78.53982  
 psh2 ((5.4d), TBDY) = Lstir2\*Astir2/(Asec\*s2) = 0.00070345  
 Lstir2 (Length of stirrups along X) = 1968.00  
 Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962

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 = 257.9541

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

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

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 = 257.9541

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

yv = 0.00092863

shv = 0.00297161

ftv = 309.5449

fyv = 257.9541

suv = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962

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 = 257.9541

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.06082368

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.03782183

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.06576367

and confined core properties:

b = 390.00

$d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.07329111$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.04557442$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07924369$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.24031351$   
 $Mu = MRc (4.14) = 5.8043E+008$   
 $u = su (4.1) = 5.5327066E-006$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.16198962$   
 $l_b = 300.00$   
 $l_d = 1851.971$   
 Calculation of  $l_b$ ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $l_d$ ,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 694.45$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$   
 $n = 30.00$

Calculation of  $Mu_{2+}$

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

$u = 5.2477290E-006$   
 $Mu = 3.2937E+008$

with full section properties:

$b = 950.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00093808$   
 $N = 20792.022$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01151713$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01151713$   
 $we (5.4c) = 0.04017143$   
 $ase ((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53375773$   
 $ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noconf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $a_{se2} (\geq a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noconf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53375773$

The definitions of  $A_{noconf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noconf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

-----  
 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.48363$   
 $p_{sh1} ((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$   
 $L_{stir1}$  (Length of stirrups along Y) = 2160.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $p_{sh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$   
 $L_{stir2}$  (Length of stirrups along Y) = 1568.00  
 $A_{stir2}$  (stirrups area) = 50.26548

-----  
 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.97078$   
 $p_{sh1} ((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$   
 $L_{stir1}$  (Length of stirrups along X) = 2560.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $p_{sh2} ((5.4d), \text{TBDY}) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$   
 $L_{stir2}$  (Length of stirrups along X) = 1968.00  
 $A_{stir2}$  (stirrups area) = 50.26548

-----  
 $A_{sec} = 562500.00$   
 $s_1 = 100.00$   
 $s_2 = 250.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 694.45$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$

$y_1 = 0.00092863$   
 $sh_1 = 0.00297161$   
 $ft_1 = 309.5449$   
 $fy_1 = 257.9541$   
 $su_1 = 0.00297161$

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

$l_o/l_{ou,min} = l_b/l_d = 0.16198962$   
 $su_1 = 0.4 * esu_{1,nominal} ((5.5), \text{TBDY}) = 0.032$

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

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

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 257.9541$

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

$y_2 = 0.00092863$   
 $sh_2 = 0.00297161$   
 $ft_2 = 309.5449$   
 $fy_2 = 257.9541$   
 $su_2 = 0.00297161$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.16198962$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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  $fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 257.9541$   
 with  $Es_2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$   
 $y_v = 0.00092863$   
 $sh_v = 0.00297161$   
 $ft_v = 309.5449$   
 $fy_v = 257.9541$   
 $su_v = 0.00297161$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.16198962$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $fsv = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 257.9541$   
 with  $Es_v = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / f_c) = 0.0179156$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / f_c) = 0.02881122$   
 $v = A_{sl,mid} / (b * d) * (fsv / f_c) = 0.03115121$   
 and confined core properties:  
 $b = 890.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / f_c) = 0.01997081$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / f_c) = 0.03211633$   
 $v = A_{sl,mid} / (b * d) * (fsv / f_c) = 0.03472476$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.19905879$   
 $Mu = MR_c (4.14) = 3.2937E+008$   
 $u = su (4.1) = 5.2477290E-006$

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Calculation of ratio  $l_b/l_d$   
 -----  
 Lap Length:  $l_b/l_d = 0.16198962$   
 $l_b = 300.00$   
 $l_d = 1851.971$   
 Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $l_{d,min}$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $fy = 694.45$   
 Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $fc'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$

$$K_{tr} = 1.37392$$

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

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 30.00$$

Calculation of  $\mu_2$ -

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

$$\mu = 5.5327066E-006$$

$$\mu = 5.8043E+008$$

with full section properties:

$$b = 450.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00198039$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, \alpha) = 0.01151713$$

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

$$\text{From (5.4b), TB DY: } \mu = 0.01151713$$

$$\text{we (5.4c) } = 0.04017143$$

$$\alpha_{se} ((5.4d), \text{TB DY}) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.53375773$$

$$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_{se2} (>= \alpha_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$$

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$$

$$p_{sh1} ((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$$

$$L_{stir1} (\text{Length of stirrups along Y}) = 2160.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$p_{sh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$$

$$L_{stir2} (\text{Length of stirrups along Y}) = 1568.00$$

$$A_{stir2} (\text{stirrups area}) = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$$

$$p_{sh1} ((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$$

$$L_{stir1} (\text{Length of stirrups along X}) = 2560.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

psh2 ((5.4d), TBDY) = Lstir2\*Astir2/(Asec\*s2) = 0.00070345  
 Lstir2 (Length of stirrups along X) = 1968.00  
 Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

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

lo/lou,min = lb/lb = 0.16198962

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 = 257.9541

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

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

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 = 257.9541

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

yv = 0.00092863

shv = 0.00297161

ftv = 309.5449

fyv = 257.9541

suv = 0.00297161

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

lo/lou,min = lb/lb = 0.16198962

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 = 257.9541

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.06082368

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.03782183

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.06576367

and confined core properties:

b = 390.00

d = 677.00

```

d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.07329111
2 = Asl,com/(b*d)*(fs2/fc) = 0.04557442
v = Asl,mid/(b*d)*(fsv/fc) = 0.07924369
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.24031351
Mu = MRc (4.14) = 5.8043E+008
u = su (4.1) = 5.5327066E-006
-----

Calculation of ratio lb/ld
-----

Lap Length: lb/ld = 0.16198962
lb = 300.00
ld = 1851.971
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
ld,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, 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 = 1.37392
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) = 250.00
n = 30.00
-----

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 1.3280E+006
-----

Calculation of Shear Strength at edge 1, Vr1 = 1.3280E+006
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VCol0
VCol0 = 1.3280E+006
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 = 33.00, but fc'^0.5 <= 8.3
MPa (22.5.3.1, ACI 318-14)
M/Vd = 2.00
Mu = 1534.054
Vu = 4.6187021E-017
d = 0.8*h = 600.00
Nu = 20792.022
Ag = 337500.00
From (11.5.4.8), ACI 318-14: Vs = Vs,jacket + Vs,core = 936062.473
where:
Vs,jacket = Vs,j1 + Vs,j2 = 837764.743
Vs,j1 = 523602.964 is calculated for section web jacket, with:
d = 600.00
Av = 157079.633

```



$f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.27777778$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$   
 $V_{s,c1} = 98297.73$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.25$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 1.0304E+006$   
 $bw = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.3280E+006$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$   
 $V_{Col0} = 1.3280E+006$   
 $knl = 1$  (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:  $f'_c = (f'_c\_jacket * Area\_jacket + f'_c\_core * Area\_core) / Area\_section = 33.00$ , but  $f'_c^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1534.054$   
 $V_u = 4.6187021E-017$   
 $d = 0.8 * h = 600.00$   
 $N_u = 20792.022$   
 $A_g = 337500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 936062.473$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 837764.743$   
 $V_{s,j1} = 523602.964$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.27777778$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$   
 $V_{s,c1} = 98297.73$  is calculated for section web core, with:

$d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.25$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 1.0304E+006$   
 $bw = 450.00$

End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
 At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
 At Shear local axis: 2  
 (Bending local axis: 3)  
 Section Type: rcjtcs

#### Constant Properties

Knowledge Factor,  $\phi = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Jacket  
 New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 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  
 New material: Steel Strength,  $f_s = 1.25 * f_{sm} = 694.45$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 450.00$   
 Max Width,  $W_{max} = 950.00$   
 Min Width,  $W_{min} = 450.00$   
 Eccentricity,  $Ecc = 250.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.22443  
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_o = 300.00$

## No FRP Wrapping

### Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = 1.3499588E-021$

EDGE -B-

Shear Force,  $V_b = -1.3499588E-021$

BOTH EDGES

Axial Force,  $F = -20792.022$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $A_{sc} = 6691.592$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{st,ten} = 1539.38$

-Compression:  $A_{st,com} = 1539.38$

-Middle:  $A_{st,mid} = 3612.832$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.22515134$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 361758.676$

with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 5.4264E+008$

$\mu_{1+} = 5.4264E+008$ , 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

$\mu_{1-} = 5.4264E+008$ , 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 5.4264E+008$

$\mu_{2+} = 5.4264E+008$ , 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

$\mu_{2-} = 5.4264E+008$ , 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:

$\mu = 4.1882964E-006$

$M_u = 5.4264E+008$

with full section properties:

$b = 450.00$

$d = 907.00$

$d' = 43.00$

$v = 0.0015437$

$N = 20792.022$

$f_c = 33.00$

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

Final value of  $\phi_{cu}$ :  $\phi_{cu}^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_c) = 0.01151713$

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

From (5.4b), TBDY:  $\phi_{cu} = 0.01151713$

$\phi_{we}$  (5.4c) = 0.04017143

$\phi_{ase}$  ((5.4d), TBDY) =  $(\phi_{ase1} * A_{ext} + \phi_{ase2} * A_{int}) / A_{sec} = 0.53375773$

$\phi_{ase1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 395025.00 is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area Aconf,max1 by a length

equal to half the clear spacing between external hoops.

AnoConf1 = 173066.667 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.53375773$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 252164.00 is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 111441.00 is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area Aconf,max2 by a length

equal to half the clear spacing between internal hoops.

AnoConf2 = 110709.333 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 2.48363$

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 2.48363

psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00301593$

Lstir1 (Length of stirrups along Y) = 2160.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d)) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00056047$

Lstir2 (Length of stirrups along Y) = 1568.00

Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 2.97078

psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00357443$

Lstir1 (Length of stirrups along X) = 2560.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00070345$

Lstir2 (Length of stirrups along X) = 1968.00

Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

lo/lou,min =  $l_b / l_d = 0.16198962$

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

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  $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,jacket} * A_{s1,ten,jacket} + f_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 257.9541$

with Es1 =  $(E_{s,jacket} * A_{s1,ten,jacket} + E_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 200000.00$

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.16198962$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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  $fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 257.9541$   
 with  $Es_2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$   
 $y_v = 0.00092863$   
 $sh_v = 0.00297161$   
 $ft_v = 309.5449$   
 $fy_v = 257.9541$   
 $suv = 0.00297161$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.16198962$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $fs_v = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 257.9541$   
 with  $Es_v = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.02948185$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.02948185$   
 $v = A_{sl,mid} / (b * d) * (fs_v / fc) = 0.06919209$

and confined core properties:

$b = 390.00$   
 $d = 877.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.03518117$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.03518117$   
 $v = A_{sl,mid} / (b * d) * (fs_v / fc) = 0.08256805$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

$su (4.9) = 0.21774786$

$\mu_u = M_{Rc} (4.14) = 5.4264E+008$

$u = su (4.1) = 4.1882964E-006$

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

Lap Length:  $l_b/l_d = 0.16198962$

$l_b = 300.00$

$l_d = 1851.971$

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

$l_{d,min}$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 694.45$

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.37392$

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

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 30.00$$

Calculation of Mu1-

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

$$\mu = 4.1882964\text{E-}006$$

$$\text{Mu} = 5.4264\text{E+}008$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u = \text{shear\_factor} * \text{Max}(c_u, c_o) = 0.01151713$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01151713$$

$$w_e \text{ (5.4c)} = 0.04017143$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53375773$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length

equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length

equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$$

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.48363$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2160.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1568.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.97078$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2560.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1968.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

```

Asec = 562500.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 694.45
fce = 33.00
From ((5.A.5), TBDY), TBDY: cc = 0.00424426
c = confinement factor = 1.22443
y1 = 0.00092863
sh1 = 0.00297161
ft1 = 309.5449
fy1 = 257.9541
su1 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 257.9541
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00092863
sh2 = 0.00297161
ft2 = 309.5449
fy2 = 257.9541
su2 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.02948185
2 = Asl,com/(b*d)*(fs2/fc) = 0.02948185
v = Asl,mid/(b*d)*(fsv/fc) = 0.06919209
and confined core properties:
b = 390.00
d = 877.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426

```

$c = \text{confinement factor} = 1.22443$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03518117$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.03518117$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08256805$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su(4.9) = 0.21774786$   
 $Mu = MRc(4.14) = 5.4264E+008$   
 $u = su(4.1) = 4.1882964E-006$

Calculation of ratio  $l_b/d$

Lap Length:  $l_b/d = 0.16198962$   
 $l_b = 300.00$   
 $l_d = 1851.971$   
 Calculation of  $l_b$ ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $l_d$ ,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 694.45$   
 Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$   
 $n = 30.00$

Calculation of  $Mu_{2+}$

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 4.1882964E-006$   
 $Mu = 5.4264E+008$

with full section properties:

$b = 450.00$   
 $d = 907.00$   
 $d' = 43.00$   
 $v = 0.0015437$   
 $N = 20792.022$   
 $f_c = 33.00$   
 $\alpha(5A.5, TBDY) = 0.002$   
 Final value of  $cu^*$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01151713$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01151713$   
 $w_e(5.4c) = 0.04017143$   
 $ase((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53375773$   
 $ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.



Aconf,min1 = 395025.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 173066.667 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.53375773$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 252164.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 111441.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 110709.333 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 2.48363$

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 2.48363  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00301593$   
Lstir1 (Length of stirrups along Y) = 2160.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d)) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00056047$   
Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 2.97078  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00357443$   
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00070345$   
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

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

lo/lou,min =  $l_b/l_d = 0.16198962$

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

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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 257.9541$

with Es1 =  $(E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

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

lo/lou,min =  $l_b/l_{b,min} = 0.16198962$

```

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 = (fsjacket*Aslcom,jacket + fscore*Aslcom,core)/Aslcom = 257.9541
with Es2 = (Esjacket*Aslcom,jacket + Escore*Aslcom,core)/Aslcom = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962
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*Aslmid,jacket + fsmid*Aslmid,core)/Aslmid = 257.9541
with Esv = (Esjacket*Aslmid,jacket + Esmid*Aslmid,core)/Aslmid = 200000.00
1 = Aslten/(b*d)*(fs1/fc) = 0.02948185
2 = Aslcom/(b*d)*(fs2/fc) = 0.02948185
v = Aslmid/(b*d)*(fsv/fc) = 0.06919209
and confined core properties:
b = 390.00
d = 877.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Aslten/(b*d)*(fs1/fc) = 0.03518117
2 = Aslcom/(b*d)*(fs2/fc) = 0.03518117
v = Aslmid/(b*d)*(fsv/fc) = 0.08256805
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.21774786
Mu = MRc (4.14) = 5.4264E+008
u = su (4.1) = 4.1882964E-006
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.16198962
lb = 300.00
ld = 1851.971
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
ld,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, 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 = 1.37392
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) = 250.00

```

$$n = 30.00$$

Calculation of Mu2-

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

$$\mu = 4.1882964E-006$$

$$Mu = 5.4264E+008$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, c_o) = 0.01151713$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01151713$$

$$w_e \text{ (5.4c)} = 0.04017143$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53375773$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$$

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2160.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1568.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2560.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1968.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

```

Asec = 562500.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 694.45
fce = 33.00
From ((5A.5), TBDY), TBDY: cc = 0.00424426
c = confinement factor = 1.22443
y1 = 0.00092863
sh1 = 0.00297161
ft1 = 309.5449
fy1 = 257.9541
su1 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 257.9541
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00092863
sh2 = 0.00297161
ft2 = 309.5449
fy2 = 257.9541
su2 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.02948185
2 = Asl,com/(b*d)*(fs2/fc) = 0.02948185
v = Asl,mid/(b*d)*(fsv/fc) = 0.06919209
and confined core properties:
b = 390.00
d = 877.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443

```

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03518117$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.03518117$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08256805$$

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

---->

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

---->

$$s_u(4.9) = 0.21774786$$

$$M_u = M_{Rc}(4.14) = 5.4264E+008$$

$$u = s_u(4.1) = 4.1882964E-006$$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.16198962$

$$l_b = 300.00$$

$$l_d = 1851.971$$

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

$l_d$ ,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 694.45$

Mean concrete strength:  $f'_c = (f'_c_{jacket} * Area_{jacket} + f'_c_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.37392$$

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

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

$$s = \max(s_{external}, s_{internal}) = 250.00$$

$$n = 30.00$$

Calculation of Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 1.6067E+006$

Calculation of Shear Strength at edge 1,  $V_{r1} = 1.6067E+006$

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

$$V_{Col0} = 1.6067E+006$$

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

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

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

Mean concrete strength:  $f'_c = (f'_c_{jacket} * Area_{jacket} + f'_c_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$M_u = 1.04067$$

$$V_u = 1.3499588E-021$$

$$d = 0.8 * h = 760.00$$

$$N_u = 20792.022$$

$$A_g = 427500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{sjacket} + V_{s,core} = 1.1114E+006$$

where:

$$V_{sjacket} = V_{sj1} + V_{sj2} = 977392.20$$

$V_{sj1} = 314161.779$  is calculated for section web jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$$V_{sj1} \text{ is multiplied by } Col,j1 = 1.00$$

$$s/d = 0.27777778$$

$V_{s,j2} = 663230.422$  is calculated for section flange jacket, with:

$$d = 760.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$$s/d = 0.13157895$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$

$$s/d = 1.25$$

$V_{s,c2} = 134042.359$  is calculated for section flange core, with:

$$d = 600.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$

$$s/d = 0.41666667$$

$$V_f((11-3)-(11.4), ACI 440) = 0.00$$

$$\text{From } (11-11), ACI 440: V_s + V_f \leq 1.3051E+006$$

$$bw = 450.00$$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.6067E+006$

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

$$V_{Col0} = 1.6067E+006$$

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

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

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

$$\text{Mean concrete strength: } f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$\mu_u = 1.04067$$

$$V_u = 1.3499588E-021$$

$$d = 0.8 * h = 760.00$$

$$N_u = 20792.022$$

$$A_g = 427500.00$$

$$\text{From } (11.5.4.8), ACI 318-14: V_s = V_{s,jacket} + V_{s,core} = 1.1114E+006$$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 977392.20$$

$V_{s,j1} = 314161.779$  is calculated for section web jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$

$$s/d = 0.27777778$$

$V_{s,j2} = 663230.422$  is calculated for section flange jacket, with:

$$d = 760.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$$s/d = 0.13157895$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.25$   
 $V_{s,c2} = 134042.359$  is calculated for section flange core, with:  
 $d = 600.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.41666667$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 1.3051E+006$   
 $b_w = 450.00$

End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
 At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1  
 At local axis: 2  
 Integration Section: (a)  
 Section Type: rcjtcs

#### Constant Properties

Knowledge Factor,  $= 1.00$   
 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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 450.00$   
 Max Width,  $W_{max} = 950.00$   
 Min Width,  $W_{min} = 450.00$   
 Eccentricity,  $Ecc = 250.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_b = 300.00$   
 No FRP Wrapping

#### Stepwise Properties

Bending Moment,  $M = -175006.178$   
 Shear Force,  $V_2 = -8018.608$   
 Shear Force,  $V_3 = 89.95386$   
 Axial Force,  $F = -21552.589$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $As_t = 0.00$   
 -Compression:  $As_c = 6691.592$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $Asl_{ten} = 1539.38$

-Compression:  $Asl_{com} = 2475.575$

-Middle:  $Asl_{mid} = 2676.637$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension:  $Asl_{ten,jacket} = 1231.504$

-Compression:  $Asl_{com,jacket} = 1859.823$

-Middle:  $Asl_{mid,jacket} = 2060.885$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $Asl_{ten,core} = 307.8761$

-Compression:  $Asl_{com,core} = 615.7522$

-Middle:  $Asl_{mid,core} = 615.7522$

Mean Diameter of Tension Reinforcement,  $DbL = 16.57143$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = 1.0^*$   $u = 0.00133904$

$u = y + p = 0.00133904$

- Calculation of  $y$  -

$y = (My * Ls / 3) / Eleff = 0.00133904$  ((4.29), Biskinis Phd))

$My = 3.7889E+008$

$Ls = M/V$  (with  $Ls > 0.1 * L$  and  $Ls < 2 * L$ ) = 1945.51

From table 10.5, ASCE 41\_17:  $Eleff = factor * Ec * Ig = 1.8350E+014$

$factor = 0.30$

$Ag = 562500.00$

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 33.00$

$N = 21552.589$

$Ec * Ig = Ec_{jacket} * Ig_{jacket} + Ec_{core} * Ig_{core} = 6.1166E+014$

Calculation of Yielding Moment  $My$

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

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 950.00$

web width,  $bw = 450.00$

flange thickness,  $t = 450.00$

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

$y_{ten} = 2.1200732E-006$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (lb/d)^{2/3}) = 239.4634$

$d = 707.00$

$y = 0.20119856$

$A = 0.01009692$

$B = 0.00476389$

with  $pt = 0.00229194$

$pc = 0.00368581$

$pv = 0.00398517$

$N = 21552.589$

$b = 950.00$

$" = 0.06082037$

$y_{comp} = 1.5661278E-005$

with  $fc = 33.00$

$Ec = 26999.444$

$y = 0.19869411$

$A = 0.00988999$

$B = 0.00462988$

with  $Es = 200000.00$

CONFIRMATION:  $y = 0.19955566 < t/d$



## Calculation of ratio $l_b/l_d$

Lap Length:  $l_d/l_{d,min} = 0.20248702$

$l_b = 300.00$

$l_d = 1481.576$

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

$l_{d,min}$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (10.3.5, ASCE 41-17)

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 555.56$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.37392$

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

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

$s = \max(s_{external}, s_{internal}) = 250.00$

$n = 30.00$

## - 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  $V_y E / V_{col} O E = 0.29138786$

$d = d_{external} = 707.00$

$s = s_{external} = 0.00$

-  $t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.0035764$

jacket:  $s_1 = A_{v1} \cdot L_{stir1} / (s_1 \cdot A_g) = 0.00301593$

$A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir1} = 2160.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2} \cdot L_{stir2} / (s_2 \cdot A_g) = 0.00056047$

$A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir2} = 1568.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

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

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

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

For the normalisation  $f_s$  of jacket is used.

$N_{UD} = 21552.589$

$A_g = 562500.00$

$f_{cE} = (f_{c,jacket} \cdot Area_{jacket} + f_{c,core} \cdot Area_{core}) / section\_area = 33.00$

$f_{yE} = (f_{y,ext\_Long\_Reinf} \cdot Area_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} \cdot Area_{int\_Long\_Reinf}) / Area_{Tot\_Long\_Rein} = 555.56$

$f_{yE} = (f_{y,ext\_Trans\_Reinf} \cdot s_1 + f_{y,int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 555.56$

$p_l = Area_{Tot\_Long\_Rein} / (b \cdot d) = 0.00996292$

$b = 950.00$

$d = 707.00$

$f_{cE} = 33.00$

End Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1

At local axis: 2

Integration Section: (a)

### Calculation No. 3

column C1, Floor 1

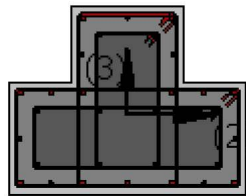
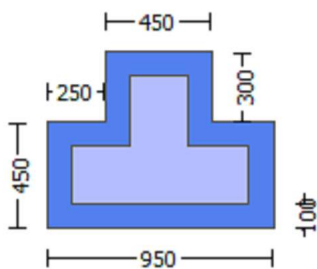
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JTC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Secondary 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

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

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

#####

Max Height, Hmax = 750.00  
 Min Height, Hmin = 450.00  
 Max Width, Wmax = 950.00  
 Min Width, Wmin = 450.00  
 Eccentricity, Ecc = 250.00  
 Jacket Thickness, tj = 100.00  
 Cover Thickness, c = 25.00  
 Element Length, L = 3000.00  
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length lo = lb = 300.00  
 No FRP Wrapping

#### Stepwise Properties

EDGE -A-  
 Bending Moment, Ma = -175006.178  
 Shear Force, Va = 89.95386  
 EDGE -B-  
 Bending Moment, Mb = -93929.214  
 Shear Force, Vb = -89.95386  
 BOTH EDGES  
 Axial Force, F = -21552.589  
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension: Aslt = 0.00  
   -Compression: Aslc = 6691.592  
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension: Asl,ten = 1539.38  
   -Compression: Asl,com = 2475.575  
   -Middle: Asl,mid = 2676.637  
 Mean Diameter of Tension Reinforcement, DbL,ten = 16.57143

New component: From table 7-7, ASCE 41\_17: Final Shear Capacity VR = 1.0\*Vn = 1.0533E+006  
 Vn ((10.3), ASCE 41-17) = knl\*VColO = 1.0533E+006  
 VCol = 1.0533E+006  
 knl = 1.00  
 displacement\_ductility\_demand = 0.00867654

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 = 25.00, but  $fc'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 M/Vd = 3.24252  
 Mu = 175006.178  
 Vu = 89.95386  
 d = 0.8\*h = 600.00  
 Nu = 21552.589  
 Ag = 337500.00  
 From (11.5.4.8), ACI 318-14: Vs = Vs,jacket + Vs,core = 842449.486  
 where:  
 Vs,jacket = Vs,j1 + Vs,j2 = 753982.237  
 Vs,j1 = 471238.898 is calculated for section web jacket, with:  
 d = 600.00  
 Av = 157079.633  
 fy = 500.00  
 s = 100.00  
 Vs,j1 is multiplied by Col,j1 = 1.00  
 s/d = 0.16666667

$V_{s,j2} = 282743.339$  is calculated for section flange jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 500.00$$

$$s = 100.00$$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$$s/d = 0.27777778$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 88467.249$$

$V_{s,c1} = 88467.249$  is calculated for section web core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 500.00$$

$$s = 250.00$$

$V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$

$$s/d = 0.56818182$$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 500.00$$

$$s = 250.00$$

$V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$

$$s/d = 1.25$$

$$V_f ((11-3)-(11.4), ACI 440) = 0.00$$

$$\text{From } (11-11), ACI 440: V_s + V_f \leq 896810.169$$

$$bw = 450.00$$

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

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

From analysis, chord rotation  $\theta = 1.1618259E-005$

$$y = (M_y * L_s / 3) / E_{eff} = 0.00133904 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 3.7889E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 1945.51$$

$$\text{From table 10.5, ASCE 41-17: } E_{eff} = \text{factor} * E_c * I_g = 1.8350E+014$$

$$\text{factor} = 0.30$$

$$A_g = 562500.00$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * A_{\text{jacket}} + f_c'_{\text{core}} * A_{\text{core}}) / A_{\text{section}} = 33.00$$

$$N = 21552.589$$

$$E_c * I_g = E_c * I_{g,jacket} + E_c * I_{g,core} = 6.1166E+014$$

Calculation of Yielding Moment  $M_y$

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

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

$$\text{flange width, } b = 950.00$$

$$\text{web width, } bw = 450.00$$

$$\text{flange thickness, } t = 450.00$$

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

$$y_{\text{ten}} = 2.1200732E-006$$

$$\text{with } ((10.1), \text{ASCE 41-17}) f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 239.4634$$

$$d = 707.00$$

$$y = 0.20119856$$

$$A = 0.01009692$$

$$B = 0.00476389$$

$$\text{with } pt = 0.00229194$$

$$pc = 0.00368581$$

$$pv = 0.00398517$$

$$N = 21552.589$$

$$b = 950.00$$

" = 0.06082037  
y\_comp = 1.5661278E-005  
with fc = 33.00  
Ec = 26999.444  
y = 0.19869411  
A = 0.00988999  
B = 0.00462988  
with Es = 200000.00  
CONFIRMATION: y = 0.19955566 < t/d

-----

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

-----

Lap Length: l<sub>d</sub>/l<sub>d,min</sub> = 0.20248702  
lb = 300.00  
l<sub>d</sub> = 1481.576  
Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
l<sub>d,min</sub> from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (10.3.5, ASCE 41-17)  
= 1  
db = 16.66667  
Mean strength value of all re-bars: f<sub>y</sub> = 555.56  
Mean concrete strength: f<sub>c'</sub> = (f<sub>c'</sub><sub>jacket</sub>\*Area<sub>jacket</sub> + f<sub>c'</sub><sub>core</sub>\*Area<sub>core</sub>)/Area<sub>section</sub> = 33.00, but f<sub>c'</sub><sup>0.5</sup> ≤ 8.3  
MPa (22.5.3.1, ACI 318-14)  
t = 1.00  
s = 0.80  
e = 1.00  
cb = 25.00  
K<sub>tr</sub> = 1.37392  
A<sub>tr</sub> = Min(A<sub>tr,x</sub>, A<sub>tr,y</sub>) = 257.6106  
where A<sub>tr,x</sub>, A<sub>tr,y</sub> are the sum of the area of all stirrup legs along X and Y local axis  
s = Max(s<sub>external</sub>, s<sub>internal</sub>) = 250.00  
n = 30.00

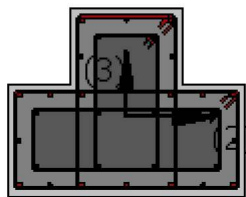
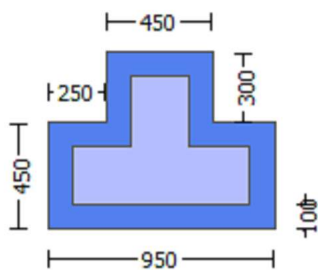
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End Of Calculation of Shear Capacity for element: column JTC1 of floor 1  
At local axis: 3  
Integration Section: (a)

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## Calculation No. 4

column C1, Floor 1  
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)  
Analysis: Uniform +X  
Check: Chord rotation capacity (  $\phi$  )  
Edge: Start  
Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $Ecc = 250.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.22443

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

No FRP Wrapping

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 4.6187021E-017$

EDGE -B-

Shear Force,  $V_b = -4.6187021E-017$

BOTH EDGES

Axial Force,  $F = -20792.022$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 6691.592$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 1539.38$

-Compression:  $As_{l,com} = 2475.575$

-Middle:  $As_{l,mid} = 2676.637$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.29138786$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 386950.491$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 5.8043E+008$

$Mu_{1+} = 3.2937E+008$ , 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

$Mu_{1-} = 5.8043E+008$ , 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 5.8043E+008$

$Mu_{2+} = 3.2937E+008$ , 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

$Mu_{2-} = 5.8043E+008$ , 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:

$\phi_u = 5.2477290E-006$

$M_u = 3.2937E+008$

with full section properties:

$b = 950.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093808$

$N = 20792.022$

$f_c = 33.00$

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

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01151713$

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

From (5.4b), TBDY:  $\phi_u = 0.01151713$

we (5.4c) = 0.04017143

$\phi_{se}$  ((5.4d), TBDY) =  $(\phi_{se1} * A_{ext} + \phi_{se2} * A_{int}) / A_{sec} = 0.53375773$

$\phi_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\phi_{se2} (>= \phi_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$   
 $psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$   
 $L_{stir1}$  (Length of stirrups along Y) = 2160.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$   
 $L_{stir2}$  (Length of stirrups along Y) = 1568.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$   
 $psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$   
 $L_{stir1}$  (Length of stirrups along X) = 2560.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$   
 $L_{stir2}$  (Length of stirrups along X) = 1968.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00424426$

$c = \text{confinement factor} = 1.22443$

$y1 = 0.00092863$

$sh1 = 0.00297161$

$ft1 = 309.5449$

$fy1 = 257.9541$

$su1 = 0.00297161$

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

$lo/lo_{min} = lb/ld = 0.16198962$

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

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  $fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 257.9541$

with  $Es1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.00092863$

$sh2 = 0.00297161$

$ft2 = 309.5449$

$fy2 = 257.9541$

$su2 = 0.00297161$

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

$lo/lo_{min} = lb/lb_{min} = 0.16198962$

$su2 = 0.4 * esu2_{nominal} ((5.5), TBDY) = 0.032$

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  $fs2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 257.9541$

with  $Es2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$

$yv = 0.00092863$



```

shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
    using (30) in Biskinis/Fardis (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 = 0.16198962
    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 = 257.9541
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0179156
2 = Asl,com/(b*d)*(fs2/fc) = 0.02881122
v = Asl,mid/(b*d)*(fsv/fc) = 0.03115121
and confined core properties:
b = 890.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
    c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.01997081
2 = Asl,com/(b*d)*(fs2/fc) = 0.03211633
v = Asl,mid/(b*d)*(fsv/fc) = 0.03472476
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.19905879
Mu = MRc (4.14) = 3.2937E+008
u = su (4.1) = 5.2477290E-006
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.16198962
lb = 300.00
ld = 1851.971
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
ld,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)
    = 1
db = 16.66667
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, 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 = 1.37392
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) = 250.00
n = 30.00
-----
-----
-----
Calculation of Mu1-
-----
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-----

```

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

$$\phi_u = 5.5327066E-006$$

$$\mu = 5.8043E+008$$

with full section properties:

$$b = 450.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00198039$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_{cu}: \phi_{cu}^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01151713$$

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

$$\text{From (5.4b), TB DY: } \phi_{cu} = 0.01151713$$

$$\phi_{we} (5.4c) = 0.04017143$$

$$\phi_{ase} ((5.4d), \text{TB DY}) = (\phi_{ase1} * A_{ext} + \phi_{ase2} * A_{int}) / A_{sec} = 0.53375773$$

$$\phi_{ase1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i d_i / 6$  as defined at (A.2).

$$\phi_{ase2} (> \phi_{ase1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i d_i / 6$  as defined at (A.2).

$$\phi_{psh,min} * F_{ywe} = \text{Min}(\phi_{psh,x} * F_{ywe}, \phi_{psh,y} * F_{ywe}) = 2.48363$$

$$\phi_{psh,x} * F_{ywe} = \phi_{psh1} * F_{ywe1} + \phi_{ps2} * F_{ywe2} = 2.48363$$

$$\phi_{psh1} ((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$$

$$L_{stir1} (\text{Length of stirrups along Y}) = 2160.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$\phi_{psh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$$

$$L_{stir2} (\text{Length of stirrups along Y}) = 1568.00$$

$$A_{stir2} (\text{stirrups area}) = 50.26548$$

$$\phi_{psh,y} * F_{ywe} = \phi_{psh1} * F_{ywe1} + \phi_{ps2} * F_{ywe2} = 2.97078$$

$$\phi_{psh1} ((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$$

$$L_{stir1} (\text{Length of stirrups along X}) = 2560.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$\phi_{psh2} ((5.4d), \text{TB DY}) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$$

$$L_{stir2} (\text{Length of stirrups along X}) = 1968.00$$

$$A_{stir2} (\text{stirrups area}) = 50.26548$$

$$A_{sec} = 562500.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \phi_{cc} = 0.00424426$$

$$\phi_c = \text{confinement factor} = 1.22443$$

```

y1 = 0.00092863
sh1 = 0.00297161
ft1 = 309.5449
fy1 = 257.9541
su1 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962
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 = 257.9541
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00092863
sh2 = 0.00297161
ft2 = 309.5449
fy2 = 257.9541
su2 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.06082368
2 = Asl,com/(b*d)*(fs2/fc) = 0.03782183
v = Asl,mid/(b*d)*(fsv/fc) = 0.06576367
and confined core properties:
b = 390.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.07329111
2 = Asl,com/(b*d)*(fs2/fc) = 0.04557442
v = Asl,mid/(b*d)*(fsv/fc) = 0.07924369
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
---->
v < vs,y2 - LHS eq.(4.5) is satisfied
---->

```

$s_u(4.9) = 0.24031351$   
 $\mu = M_{Rc}(4.14) = 5.8043E+008$   
 $u = s_u(4.1) = 5.5327066E-006$

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

Lap Length:  $l_b/l_d = 0.16198962$

$l_b = 300.00$

$l_d = 1851.971$

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

$l_d$ ,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 694.45$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.37392$

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

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

$s = \max(s_{external}, s_{internal}) = 250.00$

$n = 30.00$

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

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

$u = 5.2477290E-006$

$\mu = 3.2937E+008$

with full section properties:

$b = 950.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093808$

$N = 20792.022$

$f_c = 33.00$

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

Final value of  $\phi$ :  $\phi^* = \text{shear\_factor} \cdot \max(\phi, \phi_c) = 0.01151713$

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

From (5.4b), TBDY:  $\phi = 0.01151713$

we (5.4c)  $\phi = 0.04017143$

$\phi_{ase}((5.4d), TBDY) = (ase1 \cdot A_{ext} + ase2 \cdot A_{int}) / A_{sec} = 0.53375773$

$ase1 = \max(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length

equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b^2/6$  as defined at (A.2).

$ase2 (\geq ase1) = \max(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) \cdot (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 252164.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 111441.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 110709.333 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 2.48363

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 2.48363  
psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00301593  
Lstir1 (Length of stirrups along Y) = 2160.00  
Astir1 (stirrups area) = 78.53982  
psh2 (5.4d) = Lstir2\*Astir2/(Asec\*s2) = 0.00056047  
Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 2.97078  
psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00357443  
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) = Lstir2\*Astir2/(Asec\*s2) = 0.00070345  
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

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 = 257.9541

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

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

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 = 257.9541

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

yv = 0.00092863

shv = 0.00297161

```

ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
    using (30) in Biskinis/Fardis (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 = 0.16198962
    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 = 257.9541
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.0179156
    2 = Asl,com/(b*d)*(fs2/fc) = 0.02881122
    v = Asl,mid/(b*d)*(fsv/fc) = 0.03115121
and confined core properties:
b = 890.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
    c = confinement factor = 1.22443
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.01997081
    2 = Asl,com/(b*d)*(fs2/fc) = 0.03211633
    v = Asl,mid/(b*d)*(fsv/fc) = 0.03472476
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.19905879
Mu = MRc (4.14) = 3.2937E+008
u = su (4.1) = 5.2477290E-006
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.16198962
lb = 300.00
ld = 1851.971
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
ld,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, 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 = 1.37392
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) = 250.00
n = 30.00
-----
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Calculation of Mu2-
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Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

```

u = 5.5327066E-006  
Mu = 5.8043E+008

with full section properties:

b = 450.00

d = 707.00

d' = 43.00

v = 0.00198039

N = 20792.022

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu:  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01151713$

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

From (5.4b), TBDY:  $cu = 0.01151713$

we (5.4c) = 0.04017143

ase ((5.4d), TBDY) =  $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53375773$

ase1 =  $\text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i d_i / 6$  as defined at (A.2).

ase2 ( $\geq ase1$ ) =  $\text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

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$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i d_i / 6$  as defined at (A.2).

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$

psh1 ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

psh2 (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$

psh1 ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

$A_{stir1}$  (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00424426$

c = confinement factor = 1.22443

$y1 = 0.00092863$

```

sh1 = 0.00297161
ft1 = 309.5449
fy1 = 257.9541
su1 = 0.00297161
    using (30) in Biskinis/Fardis (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 = 0.16198962
    su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu1_nominal = 0.08,
    For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
    characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
    with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 257.9541
    with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00092863
sh2 = 0.00297161
ft2 = 309.5449
fy2 = 257.9541
su2 = 0.00297161
    using (30) in Biskinis/Fardis (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 = 0.16198962
    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 = 257.9541
    with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
    using (30) in Biskinis/Fardis (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 = 0.16198962
    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 = 257.9541
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.06082368
2 = Asl,com/(b*d)*(fs2/fc) = 0.03782183
v = Asl,mid/(b*d)*(fsv/fc) = 0.06576367
and confined core properties:
b = 390.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.07329111
2 = Asl,com/(b*d)*(fs2/fc) = 0.04557442
v = Asl,mid/(b*d)*(fsv/fc) = 0.07924369
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.24031351

```



$$\begin{aligned} \mu &= M/R_c(4.14) = 5.8043E+008 \\ u &= s_u(4.1) = 5.5327066E-006 \end{aligned}$$

Calculation of ratio  $l_b/l_d$

$$\text{Lap Length: } l_b/l_d = 0.16198962$$

$$l_b = 300.00$$

$$l_d = 1851.971$$

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

$l_d$ ,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

$$= 1$$

$$d_b = 16.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 694.45$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.37392$$

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

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

$$s = \max(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 30.00$$

$$\text{Calculation of Shear Strength } V_r = \min(V_{r1}, V_{r2}) = 1.3280E+006$$

$$\text{Calculation of Shear Strength at edge 1, } V_{r1} = 1.3280E+006$$

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

$$V_{Co10} = 1.3280E+006$$

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

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).

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

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/V_d = 2.00$$

$$\mu_u = 1534.054$$

$$V_u = 4.6187021E-017$$

$$d = 0.8 \cdot h = 600.00$$

$$N_u = 20792.022$$

$$A_g = 337500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{sj1} + V_{sj2} = 936062.473$$

where:

$$V_{sj1} = V_{sj1} + V_{sj2} = 837764.743$$

$V_{sj1} = 523602.964$  is calculated for section web jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$$V_{sj1} \text{ is multiplied by } Col_{j1} = 1.00$$

$$s/d = 0.16666667$$

$V_{sj2} = 314161.779$  is calculated for section flange jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$$V_{sj2} \text{ is multiplied by } Col_{j2} = 1.00$$

$$s/d = 0.27777778$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.25$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 1.0304E+006$   
 $bw = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.3280E+006$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$   
 $V_{Col0} = 1.3280E+006$   
 $knl = 1$  (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:  $f'_c = (f'_c\_jacket * Area\_jacket + f'_c\_core * Area\_core) / Area\_section = 33.00$ , but  $f'_c^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1534.054$   
 $V_u = 4.6187021E-017$   
 $d = 0.8 * h = 600.00$   
 $N_u = 20792.022$   
 $A_g = 337500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 936062.473$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 837764.743$   
 $V_{s,j1} = 523602.964$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.27777778$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$   
 $V_{s,c1} = 98297.73$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.25$

Vf ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440:  $V_s + V_f \leq 1.0304E+006$   
bw = 450.00

End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjctcs

#### Constant Properties

Knowledge Factor,  $\gamma = 1.00$   
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Jacket  
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
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  
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
#####  
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 450.00$   
Max Width,  $W_{max} = 950.00$   
Min Width,  $W_{min} = 450.00$   
Eccentricity,  $Ecc = 250.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.22443  
Element Length,  $L = 3000.00$   
Secondary Member  
Smooth Bars  
Ductile Steel  
With Detailing for Earthquake Resistance (including stirrups closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = 300.00$   
No FRP Wrapping

#### Stepwise Properties

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = 1.3499588E-021$   
EDGE -B-  
Shear Force,  $V_b = -1.3499588E-021$   
BOTH EDGES  
Axial Force,  $F = -20792.022$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $Asl_t = 0.00$   
 -Compression:  $Asl_c = 6691.592$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $Asl_{ten} = 1539.38$   
 -Compression:  $Asl_{com} = 1539.38$   
 -Middle:  $Asl_{mid} = 3612.832$

Calculation of Shear Capacity ratio ,  $Ve/V_r = 0.22515134$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $Ve = (M_{pr1} + M_{pr2})/l_n = 361758.676$   
 with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 5.4264E+008$

$\mu_{1+} = 5.4264E+008$ , 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

$\mu_{1-} = 5.4264E+008$ , 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 5.4264E+008$

$\mu_{2+} = 5.4264E+008$ , 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

$\mu_{2-} = 5.4264E+008$ , 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:

$\mu = 4.1882964E-006$

$\mu_{\mu} = 5.4264E+008$

with full section properties:

$b = 450.00$

$d = 907.00$

$d' = 43.00$

$v = 0.0015437$

$N = 20792.022$

$f_c = 33.00$

$\alpha_0$  (5A.5, TBDY) = 0.002

Final value of  $\alpha_u$ :  $\alpha_u = \text{shear\_factor} * \text{Max}(\alpha_c, \alpha_0) = 0.01151713$

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

From (5.4b), TBDY:  $\alpha_c = 0.01151713$

$\alpha_{ve}$  (5.4c) = 0.04017143

$\alpha_{se}$  ((5.4d), TBDY) =  $(\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.53375773$

$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

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is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length

equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\alpha_{se2} (>= \alpha_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

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$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 111441.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 110709.333 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 2.48363$

---

$psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.48363$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1*Astir1/(Asec*s1) = 0.00301593$   
 $Lstir1 \text{ (Length of stirrups along Y)} = 2160.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ (5.4d)} = Lstir2*Astir2/(Asec*s2) = 0.00056047$   
 $Lstir2 \text{ (Length of stirrups along Y)} = 1568.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

---

$psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.97078$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1*Astir1/(Asec*s1) = 0.00357443$   
 $Lstir1 \text{ (Length of stirrups along X)} = 2560.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ ((5.4d), TBDY)} = Lstir2*Astir2/(Asec*s2) = 0.00070345$   
 $Lstir2 \text{ (Length of stirrups along X)} = 1968.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

---

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962

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 = 257.9541

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

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

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 = 257.9541

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

yv = 0.00092863

shv = 0.00297161

ftv = 309.5449

fyv = 257.9541

suv = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.16198962$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
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  $y_v$ ,  $shv$ ,  $ftv$ ,  $fyv$ , 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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 257.9541$   
with  $Esv = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.02948185$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.02948185$   
 $v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.06919209$

and confined core properties:

$b = 390.00$   
 $d = 877.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.03518117$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.03518117$   
 $v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.08256805$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.21774786$   
 $Mu = MRc (4.14) = 5.4264E+008$   
 $u = su (4.1) = 4.1882964E-006$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.16198962$

$l_b = 300.00$

$l_d = 1851.971$

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

$l_d,min$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 694.45$

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $fc'^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.37392$

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

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

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 30.00$

Calculation of  $Mu_1$ -

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

$u = 4.1882964E-006$

$Mu = 5.4264E+008$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi: \phi^* = \text{shear\_factor} * \text{Max}(\phi, \phi_c) = 0.01151713$$

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

$$\text{From (5.4b), TB DY: } \phi = 0.01151713$$

$$\phi_e (5.4c) = 0.04017143$$

$$\phi_e ((5.4d), \text{TB DY}) = (\phi_{e1} * A_{ext} + \phi_{e2} * A_{int}) / A_{sec} = 0.53375773$$

$$\phi_{e1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i d_i / 6$  as defined at (A.2).

$$\phi_{e2} (> \phi_{e1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i d_i / 6$  as defined at (A.2).

$$\phi_{sh,min} * \phi_{ywe} = \text{Min}(\phi_{sh,x} * \phi_{ywe}, \phi_{sh,y} * \phi_{ywe}) = 2.48363$$

$$\phi_{sh,x} * \phi_{ywe} = \phi_{sh1} * \phi_{ywe1} + \phi_{sh2} * \phi_{ywe2} = 2.48363$$

$$\phi_{sh1} ((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$$

$$L_{stir1} (\text{Length of stirrups along Y}) = 2160.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$\phi_{sh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$$

$$L_{stir2} (\text{Length of stirrups along Y}) = 1568.00$$

$$A_{stir2} (\text{stirrups area}) = 50.26548$$

$$\phi_{sh,y} * \phi_{ywe} = \phi_{sh1} * \phi_{ywe1} + \phi_{sh2} * \phi_{ywe2} = 2.97078$$

$$\phi_{sh1} ((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$$

$$L_{stir1} (\text{Length of stirrups along X}) = 2560.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$\phi_{sh2} ((5.4d), \text{TB DY}) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$$

$$L_{stir2} (\text{Length of stirrups along X}) = 1968.00$$

$$A_{stir2} (\text{stirrups area}) = 50.26548$$

$$A_{sec} = 562500.00$$

$$s_1 = 100.00$$

$$s_2 = 250.00$$

$$\phi_{ywe1} = 694.45$$

$$\phi_{ywe2} = 694.45$$

$$\phi_{ce} = 33.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \phi_c = 0.00424426$$

$$\phi_c = \text{confinement factor} = 1.22443$$

$$y_1 = 0.00092863$$

$$sh_1 = 0.00297161$$

$$ft_1 = 309.5449$$

$$fy_1 = 257.9541$$

```

su1 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 257.9541
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00092863
sh2 = 0.00297161
ft2 = 309.5449
fy2 = 257.9541
su2 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.02948185
2 = Asl,com/(b*d)*(fs2/fc) = 0.02948185
v = Asl,mid/(b*d)*(fsv/fc) = 0.06919209
and confined core properties:
b = 390.00
d = 877.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.03518117
2 = Asl,com/(b*d)*(fs2/fc) = 0.03518117
v = Asl,mid/(b*d)*(fsv/fc) = 0.08256805
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.21774786
Mu = MRc (4.14) = 5.4264E+008
u = su (4.1) = 4.1882964E-006

```



#### Calculation of ratio $l_b/d$

Lap Length:  $l_b/d = 0.16198962$

$l_b = 300.00$

$d = 1851.971$

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

$l_b$ ,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

$= 1$

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 694.45$

Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot Area_{jacket} + f'_{c\_core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.37392$

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

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

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 30.00$

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

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

$\mu = 4.1882964E-006$

$\mu_u = 5.4264E+008$

with full section properties:

$b = 450.00$

$d = 907.00$

$d' = 43.00$

$v = 0.0015437$

$N = 20792.022$

$f'_c = 33.00$

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

Final value of  $\phi_c$ :  $\phi_c = \text{shear\_factor} \cdot \text{Max}(\phi_c, \phi_c) = 0.01151713$

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

From (5.4b), TBDY:  $\phi_c = 0.01151713$

$\phi_{we}$  (5.4c) = 0.04017143

$\phi_{ase}$  ((5.4d), TBDY) =  $(\phi_{ase1} \cdot A_{ext} + \phi_{ase2} \cdot A_{int}) / A_{sec} = 0.53375773$

$\phi_{ase1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length

equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b^2/6$  as defined at (A.2).

$\phi_{ase2} (\geq \phi_{ase1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) \cdot (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 110709.333 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 2.48363$

---

$psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.48363$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1*Astir1/(Asec*s1) = 0.00301593$   
 $Lstir1 \text{ (Length of stirrups along Y)} = 2160.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ (5.4d)} = Lstir2*Astir2/(Asec*s2) = 0.00056047$   
 $Lstir2 \text{ (Length of stirrups along Y)} = 1568.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

---

$psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.97078$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1*Astir1/(Asec*s1) = 0.00357443$   
 $Lstir1 \text{ (Length of stirrups along X)} = 2560.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ ((5.4d), TBDY)} = Lstir2*Astir2/(Asec*s2) = 0.00070345$   
 $Lstir2 \text{ (Length of stirrups along X)} = 1968.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

---

$Asec = 562500.00$   
 $s1 = 100.00$   
 $s2 = 250.00$   
 $fywe1 = 694.45$   
 $fywe2 = 694.45$   
 $fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$

$y1 = 0.00092863$   
 $sh1 = 0.00297161$   
 $ft1 = 309.5449$   
 $fy1 = 257.9541$   
 $su1 = 0.00297161$

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

$lo/lou,min = lb/ld = 0.16198962$

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

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  $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 257.9541$

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

$y2 = 0.00092863$   
 $sh2 = 0.00297161$   
 $ft2 = 309.5449$   
 $fy2 = 257.9541$   
 $su2 = 0.00297161$

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

$lo/lou,min = lb/lb,min = 0.16198962$

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

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  $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 257.9541$

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

$yv = 0.00092863$   
 $shv = 0.00297161$   
 $ftv = 309.5449$   
 $fyv = 257.9541$   
 $suv = 0.00297161$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.16198962$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
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  $fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 257.9541$   
with  $Esv = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.02948185$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.02948185$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.06919209$   
and confined core properties:  
 $b = 390.00$   
 $d = 877.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.03518117$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.03518117$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.08256805$   
Case/Assumption: Unconfined full section - Steel rupture  
'satisfies Eq. (4.3)  
--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
--->  
 $su (4.9) = 0.21774786$   
 $Mu = MRc (4.14) = 5.4264E+008$   
 $u = su (4.1) = 4.1882964E-006$   
-----  
Calculation of ratio  $l_b/l_d$   
-----  
Lap Length:  $l_b/l_d = 0.16198962$   
 $l_b = 300.00$   
 $l_d = 1851.971$   
Calculation of  $l_b,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $l_d,min$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
 $= 1$   
 $db = 16.66667$   
Mean strength value of all re-bars:  $fy = 694.45$   
Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $fc'^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = Min(A_{tr,x}, A_{tr,y}) = 257.6106$   
where  $A_{tr,x}, A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = Max(s_{external}, s_{internal}) = 250.00$   
 $n = 30.00$   
-----  
-----  
Calculation of  $Mu_2$ -  
-----  
-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 4.1882964E-006$   
 $Mu = 5.4264E+008$   
-----  
with full section properties:

$b = 450.00$   
 $d = 907.00$   
 $d' = 43.00$   
 $v = 0.0015437$   
 $N = 20792.022$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = shear\_factor * Max(cu, cc) = 0.01151713$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01151713$   
 $we (5.4c) = 0.04017143$   
 $ase ((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53375773$   
 $ase1 = Max(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.  
 $A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i d_i / 6$  as defined at (A.2).  
 $ase2 (>= ase1) = Max(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
 $A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.  
 $A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i d_i / 6$  as defined at (A.2).  
 $psh_{min} * F_{ywe} = Min(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$

---

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$   
 $psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$   
 $L_{stir1}$  (Length of stirrups along Y) = 2160.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$   
 $L_{stir2}$  (Length of stirrups along Y) = 1568.00  
 $A_{stir2}$  (stirrups area) = 50.26548

---

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$   
 $psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$   
 $L_{stir1}$  (Length of stirrups along X) = 2560.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$   
 $L_{stir2}$  (Length of stirrups along X) = 1968.00  
 $A_{stir2}$  (stirrups area) = 50.26548

---

$A_{sec} = 562500.00$   
 $s1 = 100.00$   
 $s2 = 250.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 694.45$   
 $f_{ce} = 33.00$   
 From ((5.A5), TBDY), TBDY:  $cc = 0.00424426$   
 $c =$  confinement factor = 1.22443  
 $y1 = 0.00092863$   
 $sh1 = 0.00297161$   
 $ft1 = 309.5449$   
 $fy1 = 257.9541$   
 $su1 = 0.00297161$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.16198962$   
 $su_1 = 0.4 \cdot esu_{1,nominal} ((5.5), TBDY) = 0.032$   
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  $fs_1 = (fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 257.9541$   
with  $Es_1 = (Es_{jacket} \cdot Asl_{ten,jacket} + Es_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 200000.00$   
 $y_2 = 0.00092863$   
 $sh_2 = 0.00297161$   
 $ft_2 = 309.5449$   
 $fy_2 = 257.9541$   
 $su_2 = 0.00297161$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.16198962$   
 $su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 257.9541$   
with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.00092863$   
 $sh_v = 0.00297161$   
 $ft_v = 309.5449$   
 $fy_v = 257.9541$   
 $suv = 0.00297161$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.16198962$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
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  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 257.9541$   
with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.02948185$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.02948185$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.06919209$   
and confined core properties:  
 $b = 390.00$   
 $d = 877.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.03518117$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.03518117$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.08256805$   
Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)  
--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
--->  
 $su (4.9) = 0.21774786$   
 $Mu = MRc (4.14) = 5.4264E+008$   
 $u = su (4.1) = 4.1882964E-006$

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

Lap Length:  $l_b/l_d = 0.16198962$

$l_b = 300.00$

$l_d = 1851.971$

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

$l_d$ ,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 694.45$

Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot Area\_jacket + f'_{c\_core} \cdot Area\_core) / Area\_section = 33.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.37392$

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

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

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$

$n = 30.00$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.6067E+006$

Calculation of Shear Strength at edge 1,  $V_{r1} = 1.6067E+006$

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

$V_{Col0} = 1.6067E+006$

$k_{nl} = 1$  (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:  $f'_c = (f'_{c\_jacket} \cdot Area\_jacket + f'_{c\_core} \cdot Area\_core) / Area\_section = 33.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.04067$

$V_u = 1.3499588E-021$

$d = 0.8 \cdot h = 760.00$

$N_u = 20792.022$

$A_g = 427500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 1.1114E+006$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 977392.20$

$V_{sj1} = 314161.779$  is calculated for section web jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{sj1}$  is multiplied by  $Col_{j1} = 1.00$

$s/d = 0.27777778$

$V_{sj2} = 663230.422$  is calculated for section flange jacket, with:

$d = 760.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{sj2}$  is multiplied by  $Col_{j2} = 1.00$

$s/d = 0.13157895$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.25$   
 $V_{s,c2} = 134042.359$  is calculated for section flange core, with:  
 $d = 600.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.41666667$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 1.3051E+006$   
 $bw = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.6067E+006$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$   
 $V_{Col0} = 1.6067E+006$   
 $knl = 1$  (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:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.04067$   
 $V_u = 1.3499588E-021$   
 $d = 0.8 * h = 760.00$   
 $N_u = 20792.022$   
 $A_g = 427500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 1.1114E+006$   
 where:  
 $V_{sjacket} = V_{sj1} + V_{sj2} = 977392.20$   
 $V_{sj1} = 314161.779$  is calculated for section web jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{sj1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.27777778$   
 $V_{sj2} = 663230.422$  is calculated for section flange jacket, with:  
 $d = 760.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{sj2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.13157895$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.25$   
 $V_{s,c2} = 134042.359$  is calculated for section flange core, with:  
 $d = 600.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.41666667$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 1.3051E+006$   
 $bw = 450.00$

End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1  
At local axis: 3  
Integration Section: (a)  
Section Type: rcjtcs

#### Constant Properties

Knowledge Factor,  $\gamma = 1.00$   
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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 450.00$   
Max Width,  $W_{max} = 950.00$   
Min Width,  $W_{min} = 450.00$   
Eccentricity,  $E_{cc} = 250.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Secondary Member  
Smooth Bars  
Ductile Steel  
With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_b = 300.00$   
No FRP Wrapping

#### Stepwise Properties

Bending Moment,  $M = -2.4234E+007$   
Shear Force,  $V_2 = -8018.608$   
Shear Force,  $V_3 = 89.95386$   
Axial Force,  $F = -21552.589$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{sl,t} = 0.00$   
-Compression:  $A_{sl,c} = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten} = 1539.38$   
-Compression:  $A_{sl,com} = 1539.38$   
-Middle:  $A_{sl,mid} = 3612.832$   
Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten,jacket} = 1231.504$   
-Compression:  $A_{sl,com,jacket} = 1231.504$   
-Middle:  $A_{sl,mid,jacket} = 2689.203$   
Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten,core} = 307.8761$   
-Compression:  $A_{sl,com,core} = 307.8761$   
-Middle:  $A_{sl,mid,core} = 923.6282$   
Mean Diameter of Tension Reinforcement,  $Db_L = 16.57143$



New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = 1.0 \cdot u = 0.00188057$   
 $u = y + p = 0.00188057$

- Calculation of  $y$  -

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00188057$  ((4.29), Biskinis Phd))  
 $M_y = 5.2059E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 3022.232  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 2.7887E+014$   
 $factor = 0.30$   
 $A_g = 562500.00$   
Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 33.00$   
 $N = 21552.589$   
 $E_c \cdot I_g = E_{c,jacket} \cdot I_{g,jacket} + E_{c,core} \cdot I_{g,core} = 9.2958E+014$

Calculation of Yielding Moment  $M_y$

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

$y = \min(y_{ten}, y_{com})$   
 $y_{ten} = 1.7803416E-006$   
with ((10.1), ASCE 41-17)  $f_y = \min(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 239.4634$   
 $d = 907.00$   
 $y = 0.25852163$   
 $A = 0.01661545$   
 $B = 0.00880662$   
with  $p_t = 0.0037716$   
 $p_c = 0.0037716$   
 $p_v = 0.00885172$   
 $N = 21552.589$   
 $b = 450.00$   
 $" = 0.04740904$   
 $y_{comp} = 9.4779300E-006$   
with  $fc = 33.00$   
 $E_c = 26999.444$   
 $y = 0.25592389$   
 $A = 0.01627492$   
 $B = 0.0085861$   
with  $E_s = 200000.00$

Calculation of ratio  $I_b / I_d$

Lap Length:  $I_d / I_{d,min} = 0.20248702$   
 $I_b = 300.00$   
 $I_d = 1481.576$   
Calculation of  $I$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $I_{d,min}$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (10.3.5, ASCE 41-17)  
 $= 1$   
 $db = 16.66667$   
Mean strength value of all re-bars:  $f_y = 555.56$   
Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$   
 $n = 30.00$

- 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  $V_{yE}/V_{Col0E} = 0.22515134$

$d = d_{\text{external}} = 907.00$

$s = s_{\text{external}} = 0.00$

-  $t = s_1 + s_2 + 2 \cdot t_f/bw \cdot (f_{fe}/f_s) = 0.00427788$

jacket:  $s_1 = A_{v1} \cdot L_{stir1}/(s_1 \cdot A_g) = 0.00357443$

$A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir1} = 2560.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2} \cdot L_{stir2}/(s_2 \cdot A_g) = 0.00070345$

$A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir2} = 1968.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

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.

$NUD = 21552.589$

$A_g = 562500.00$

$f_{cE} = (f_{c\_jacket} \cdot \text{Area\_jacket} + f_{c\_core} \cdot \text{Area\_core})/\text{section\_area} = 33.00$

$f_{yE} = (f_{y\_ext\_Long\_Reinf} \cdot \text{Area\_ext\_Long\_Reinf} + f_{y\_int\_Long\_Reinf} \cdot \text{Area\_int\_Long\_Reinf})/\text{Area\_Tot\_Long\_Rein} = 555.56$

$f_{ytE} = (f_{y\_ext\_Trans\_Reinf} \cdot s_1 + f_{y\_int\_Trans\_Reinf} \cdot s_2)/(s_1 + s_2) = 555.56$

$\rho_l = \text{Area\_Tot\_Long\_Rein}/(b \cdot d) = 0.01639493$

$b = 450.00$

$d = 907.00$

$f_{cE} = 33.00$

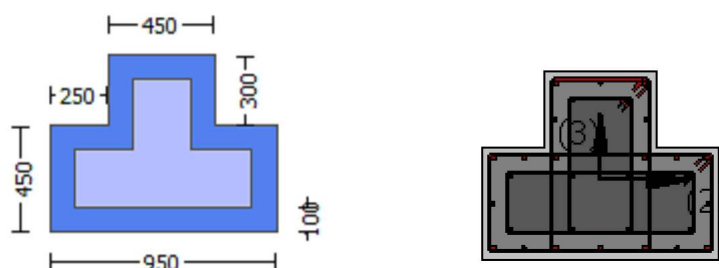
End Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1

At local axis: 3

Integration Section: (a)

## Calculation No. 5

column C1, Floor 1  
 Limit State: Operational Level (data interpolation between analysis steps 1 and 2)  
 Analysis: Uniform +X  
 Check: Shear capacity VRd  
 Edge: End  
 Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JTC1 of floor 1  
 At local axis: 2  
 Integration Section: (b)  
 Section Type: rcjtcs

#### Constant Properties

-----  
 Knowledge Factor,  $\gamma = 1.00$   
 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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$   
 New material of Secondary 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  
 New material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
 Concrete Elasticity,  $E_c = 26999.444$   
 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  
 New material: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material: Steel Strength,  $f_s = f_{sm} = 555.56$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 450.00$   
 Max Width,  $W_{max} = 950.00$   
 Min Width,  $W_{min} = 450.00$   
 Eccentricity,  $Ecc = 250.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$   
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_o = l_b = 300.00$   
 No FRP Wrapping

#### Stepwise Properties

EDGE -A-  
 Bending Moment,  $M_a = -2.4234E+007$   
 Shear Force,  $V_a = -8018.608$   
 EDGE -B-  
 Bending Moment,  $M_b = 173791.562$   
 Shear Force,  $V_b = 8018.608$   
 BOTH EDGES  
 Axial Force,  $F = -21552.589$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{st} = 0.00$   
   -Compression:  $A_{sc} = 6691.592$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{st,ten} = 1539.38$   
   -Compression:  $A_{st,com} = 1539.38$   
   -Middle:  $A_{st,mid} = 3612.832$   
 Mean Diameter of Tension Reinforcement,  $D_{bL,ten} = 16.57143$

New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 1.4321E+006$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{CoI} = 1.4321E+006$   
 $V_{CoI} = 1.4321E+006$   
 $k_n = 1.00$   
 displacement\_ductility\_demand = 0.07077847

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:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 25.00$ , but  $f_c'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/V_d = 2.00$   
 $M_u = 173791.562$   
 $V_u = 8018.608$   
 $d = 0.8 \cdot h = 760.00$   
 $N_u = 21552.589$   
 $A_g = 427500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 1.0003E+006$   
 where:  
 $V_{sjacket} = V_{sj1} + V_{sj2} = 879645.943$   
 $V_{sj1} = 282743.339$  is calculated for section web jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{sj1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.27777778$   
 $V_{sj2} = 596902.604$  is calculated for section flange jacket, with:  
 $d = 760.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{sj2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.13157895$

$V_{s,c1} = V_{s,c1} + V_{s,c2} = 120637.158$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 500.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.25$   
 $V_{s,c2} = 120637.158$  is calculated for section flange core, with:  
 $d = 600.00$   
 $A_v = 100530.965$   
 $f_y = 500.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.41666667$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 1.1360E+006$   
 $bw = 450.00$

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

- Calculation of  $\phi / y$  for END B -  
for rotation axis 3 and integ. section (b)

From analysis, chord rotation  $\theta = 1.3212486E-005$   
 $y = (M_y * L_s / 3) / E_{eff} = 0.00018667$  ((4.29), Biskinis Phd)  
 $M_y = 5.2059E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) =  $300.00$   
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.7887E+014$   
 $factor = 0.30$   
 $A_g = 562500.00$   
 Mean concrete strength:  $f'_c = (f'_c\_jacket * Area\_jacket + f'_c\_core * Area\_core) / Area\_section = 33.00$   
 $N = 21552.589$   
 $E_c * I_g = E_c\_jacket * I_g\_jacket + E_c\_core * I_g\_core = 9.2958E+014$

Calculation of Yielding Moment  $M_y$

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

$y = \min(y_{ten}, y_{com})$   
 $y_{ten} = 1.7803416E-006$   
 with ((10.1), ASCE 41-17)  $f_y = \min(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 239.4634$   
 $d = 907.00$   
 $y = 0.25852163$   
 $A = 0.01661545$   
 $B = 0.00880662$   
 with  $pt = 0.0037716$   
 $pc = 0.0037716$   
 $pv = 0.00885172$   
 $N = 21552.589$   
 $b = 450.00$   
 $" = 0.04740904$   
 $y_{comp} = 9.4779300E-006$   
 with  $f_c = 33.00$   
 $E_c = 26999.444$   
 $y = 0.25592389$   
 $A = 0.01627492$   
 $B = 0.0085861$   
 with  $E_s = 200000.00$

Calculation of ratio  $I_b / I_d$

Lap Length:  $l_d/l_{d,min} = 0.20248702$

$l_b = 300.00$

$l_d = 1481.576$

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

$l_{d,min}$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (10.3.5, ASCE 41-17)

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 555.56$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.37392$

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

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

$s = \max(s_{external}, s_{internal}) = 250.00$

$n = 30.00$

End Of Calculation of Shear Capacity for element: column JTC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 6

column C1, Floor 1

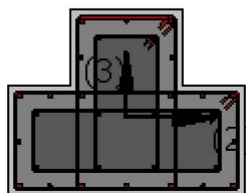
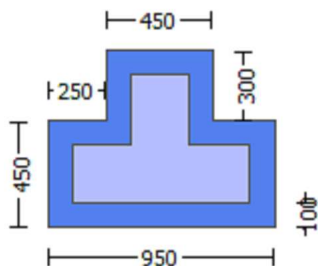
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\phi$ )

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjtcs

## Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $Ecc = 250.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.22443

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

No FRP Wrapping

## Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 4.6187021E-017$

EDGE -B-

Shear Force,  $V_b = -4.6187021E-017$

BOTH EDGES

Axial Force,  $F = -20792.022$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 6691.592$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 1539.38$

-Compression:  $As_{l,com} = 2475.575$

-Middle:  $As_{l,mid} = 2676.637$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.29138786$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 386950.491$

with

$$Mpr1 = \text{Max}(Mu1+, Mu1-) = 5.8043E+008$$

Mu1+ = 3.2937E+008, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

Mu1- = 5.8043E+008, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$$Mpr2 = \text{Max}(Mu2+, Mu2-) = 5.8043E+008$$

Mu2+ = 3.2937E+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- = 5.8043E+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:

$$\phi_u = 5.2477290E-006$$

$$Mu = 3.2937E+008$$

with full section properties:

$$b = 950.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093808$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01151713$$

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

$$\text{From (5.4b), TB DY: } \phi_u = 0.01151713$$

$$\phi_{ue} \text{ (5.4c)} = 0.04017143$$

$$a_{se} \text{ ((5.4d), TB DY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53375773$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$$

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$$

$$p_{sh1} \text{ ((5.4d), TB DY)} = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2160.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1568.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$



$psh\_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$   
 $psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$   
 $L_{stir1} \text{ (Length of stirrups along X)} = 2560.00$   
 $A_{stir1} \text{ (stirrups area)} = 78.53982$   
 $psh2 ((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$   
 $L_{stir2} \text{ (Length of stirrups along X)} = 1968.00$   
 $A_{stir2} \text{ (stirrups area)} = 50.26548$

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962

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 = 257.9541

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

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

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 = 257.9541

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

yv = 0.00092863

shv = 0.00297161

ftv = 309.5449

fyv = 257.9541

suv = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962

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 = 257.9541

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0179156

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.02881122

$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03115121$   
 and confined core properties:  
 $b = 890.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.01997081$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.03211633$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03472476$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.19905879$   
 $Mu = MRc (4.14) = 3.2937E+008$   
 $u = su (4.1) = 5.2477290E-006$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.16198962$   
 $l_b = 300.00$   
 $l_d = 1851.971$   
 Calculation of  $l_b,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $l_d,min$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 694.45$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$   
 $n = 30.00$

Calculation of  $Mu1$ -

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 5.5327066E-006$   
 $Mu = 5.8043E+008$

with full section properties:

$b = 450.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00198039$   
 $N = 20792.022$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01151713$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01151713$   
 $we (5.4c) = 0.04017143$   
 $ase ((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53375773$   
 $ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max1 = 464100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 395025.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 173066.667 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

ase2 ( $\geq$  ase1) =  $\text{Max}(((\text{Aconf,max2}-\text{AnoConf2})/\text{Aconf,max2}) * (\text{Aconf,min2}/\text{Aconf,max2}), 0) = 0.53375773$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 252164.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 111441.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 110709.333 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min\*Fywe =  $\text{Min}(\text{psh,x}*Fywe, \text{psh,y}*Fywe) = 2.48363$

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 2.48363

psh1 ((5.4d), TBDY) =  $\text{Lstir1}*Astir1/(\text{Asec}*s1) = 0.00301593$

Lstir1 (Length of stirrups along Y) = 2160.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) =  $\text{Lstir2}*Astir2/(\text{Asec}*s2) = 0.00056047$

Lstir2 (Length of stirrups along Y) = 1568.00

Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 2.97078

psh1 ((5.4d), TBDY) =  $\text{Lstir1}*Astir1/(\text{Asec}*s1) = 0.00357443$

Lstir1 (Length of stirrups along X) = 2560.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) =  $\text{Lstir2}*Astir2/(\text{Asec}*s2) = 0.00070345$

Lstir2 (Length of stirrups along X) = 1968.00

Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

using (30) in Biskinis/Fardis (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 = 0.16198962

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 =  $(fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 257.9541$

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

y2 = 0.00092863

sh2 = 0.00297161

```

ft2 = 309.5449
fy2 = 257.9541
su2 = 0.00297161
    using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
    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 = 257.9541
    with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
    yv = 0.00092863
    shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 0.16198962
    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 = 257.9541
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.06082368
    2 = Asl,com/(b*d)*(fs2/fc) = 0.03782183
    v = Asl,mid/(b*d)*(fsv/fc) = 0.06576367
and confined core properties:
b = 390.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.07329111
    2 = Asl,com/(b*d)*(fs2/fc) = 0.04557442
    v = Asl,mid/(b*d)*(fsv/fc) = 0.07924369
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

```

```

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

```

```

su (4.9) = 0.24031351
Mu = MRc (4.14) = 5.8043E+008
u = su (4.1) = 5.5327066E-006

```

Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.16198962
lb = 300.00
lb = 1851.971

```

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
lb,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

```

= 1
db = 16.66667
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, but fc'^0.5 <= 8.3
MPa (22.5.3.1, ACI 318-14)
t = 1.00

```

$s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$   
 where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$   
 $n = 30.00$

Calculation of  $\mu_{2+}$

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

$\mu = 5.2477290\text{E-}006$   
 $\mu_{2+} = 3.2937\text{E+}008$

with full section properties:

$b = 950.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00093808$   
 $N = 20792.022$

$f_c = 33.00$

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

Final value of  $\mu_{cu}$ :  $\mu_{cu}^* = \text{shear\_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.01151713$

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

From (5.4b), TB DY:  $\mu_{cu} = 0.01151713$

we (5.4c) = 0.04017143

$\alpha_{se}((5.4d), \text{TB DY}) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.53375773$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.53375773$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\alpha_{se2} (> \alpha_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.53375773$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max2}} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{\text{conf,min2}} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max2}}$  by a length equal to half the clear spacing between internal hoops.

$A_{\text{noConf2}} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$

$psh1 ((5.4d), TBDY) = Lstir1 * Astir1 / (Asec * s1) = 0.00357443$   
 $Lstir1$  (Length of stirrups along X) = 2560.00  
 $Astir1$  (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = Lstir2 * Astir2 / (Asec * s2) = 0.00070345$   
 $Lstir2$  (Length of stirrups along X) = 1968.00  
 $Astir2$  (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

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

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

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

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 257.9541

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

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

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

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

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

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 257.9541

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

yv = 0.00092863

shv = 0.00297161

ftv = 309.5449

fyv = 257.9541

suv = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

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  $\text{Min}(1, 1.25 * (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 257.9541

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0179156

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.02881122

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.03115121

and confined core properties:

$$b = 890.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 40.40604$$

$$cc (5A.5, TBDY) = 0.00424426$$

$$c = \text{confinement factor} = 1.22443$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.01997081$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.03211633$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03472476$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

$$s_u (4.9) = 0.19905879$$

$$M_u = M_{Rc} (4.14) = 3.2937E+008$$

$$u = s_u (4.1) = 5.2477290E-006$$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.16198962$

$$l_b = 300.00$$

$$l_d = 1851.971$$

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

$l_d, \min$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

$$= 1$$

$$d_b = 16.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 694.45$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.37392$$

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

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 30.00$$

Calculation of  $M_u2$ -

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

$$u = 5.5327066E-006$$

$$M_u = 5.8043E+008$$

with full section properties:

$$b = 450.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00198039$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_o) = 0.01151713$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01151713$$

$$w_e (5.4c) = 0.04017143$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53375773$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00424426$

$c$  = confinement factor = 1.22443

$y1 = 0.00092863$

$sh1 = 0.00297161$

$ft1 = 309.5449$

$fy1 = 257.9541$

$su1 = 0.00297161$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.16198962$

$su1 = 0.4 * esu1_{nominal}$  ((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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 257.9541$

with  $Es1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y2 = 0.00092863$

$sh2 = 0.00297161$

$ft2 = 309.5449$



```

fy2 = 257.9541
su2 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.06082368
2 = Asl,com/(b*d)*(fs2/fc) = 0.03782183
v = Asl,mid/(b*d)*(fsv/fc) = 0.06576367
and confined core properties:
b = 390.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.07329111
2 = Asl,com/(b*d)*(fs2/fc) = 0.04557442
v = Asl,mid/(b*d)*(fsv/fc) = 0.07924369

```

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

```

--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.24031351
Mu = MRc (4.14) = 5.8043E+008
u = su (4.1) = 5.5327066E-006

```

#### Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.16198962
lb = 300.00
lb = 1851.971
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
lb,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, but fc'^0.5 <= 8.3
MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80

```

$e = 1.00$   
 $cb = 25.00$   
 $Ktr = 1.37392$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$   
 $n = 30.00$

---

Calculation of Shear Strength  $Vr = \text{Min}(Vr1, Vr2) = 1.3280E+006$

---

Calculation of Shear Strength at edge 1,  $Vr1 = 1.3280E+006$   
 $Vr1 = VCol \text{ ((10.3), ASCE 41-17)} = knl * VCol0$   
 $VCol0 = 1.3280E+006$   
 $knl = 1$  (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:  $fc' = (fc'_{\text{jacket}} * Area_{\text{jacket}} + fc'_{\text{core}} * Area_{\text{core}}) / Area_{\text{section}} = 33.00$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $Mu = 1534.054$   
 $Vu = 4.6187021E-017$   
 $d = 0.8 * h = 600.00$   
 $Nu = 20792.022$   
 $Ag = 337500.00$   
 From (11.5.4.8), ACI 318-14:  $Vs = Vs_{\text{jacket}} + Vs_{\text{core}} = 936062.473$   
 where:  
 $Vs_{\text{jacket}} = Vs_{j1} + Vs_{j2} = 837764.743$   
 $Vs_{j1} = 523602.964$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $Av = 157079.633$   
 $fy = 555.56$   
 $s = 100.00$   
 $Vs_{j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.16666667$   
 $Vs_{j2} = 314161.779$  is calculated for section flange jacket, with:  
 $d = 360.00$   
 $Av = 157079.633$   
 $fy = 555.56$   
 $s = 100.00$   
 $Vs_{j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.27777778$   
 $Vs_{\text{core}} = Vs_{c1} + Vs_{c2} = 98297.73$   
 $Vs_{c1} = 98297.73$  is calculated for section web core, with:  
 $d = 440.00$   
 $Av = 100530.965$   
 $fy = 555.56$   
 $s = 250.00$   
 $Vs_{c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $Vs_{c2} = 0.00$  is calculated for section flange core, with:  
 $d = 200.00$   
 $Av = 100530.965$   
 $fy = 555.56$   
 $s = 250.00$   
 $Vs_{c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.25$   
 $Vf \text{ ((11-3)-(11.4), ACI 440)} = 0.00$   
 From (11-11), ACI 440:  $Vs + Vf \leq 1.0304E+006$   
 $bw = 450.00$

---

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.3280E+006$

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

$V_{Col0} = 1.3280E+006$

$knl = 1$  (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:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 1534.054$

$V_u = 4.6187021E-017$

$d = 0.8 * h = 600.00$

$N_u = 20792.022$

$A_g = 337500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 936062.473$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 837764.743$

$V_{sj1} = 523602.964$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{sj1}$  is multiplied by  $Col_{j1} = 1.00$

$s/d = 0.16666667$

$V_{sj2} = 314161.779$  is calculated for section flange jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{sj2}$  is multiplied by  $Col_{j2} = 1.00$

$s/d = 0.27777778$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col_{c1} = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col_{c2} = 0.00$

$s/d = 1.25$

$V_f ((11-3)-(11.4), ACI 440) = 0.00$

From (11-11), ACI 440:  $V_s + V_f \leq 1.0304E+006$

$bw = 450.00$

End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\phi = 1.00$   
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Jacket  
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
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  
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
#####  
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 450.00$   
Max Width,  $W_{max} = 950.00$   
Min Width,  $W_{min} = 450.00$   
Eccentricity,  $E_{cc} = 250.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.22443  
Element Length,  $L = 3000.00$   
Secondary Member  
Smooth Bars  
Ductile Steel  
With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = 300.00$   
No FRP Wrapping

#### Stepwise Properties

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = 1.3499588E-021$   
EDGE -B-  
Shear Force,  $V_b = -1.3499588E-021$   
BOTH EDGES  
Axial Force,  $F = -20792.022$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{sl,t} = 0.00$   
-Compression:  $A_{sl,c} = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten} = 1539.38$   
-Compression:  $A_{sl,com} = 1539.38$   
-Middle:  $A_{sl,mid} = 3612.832$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.22515134$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 361758.676$   
with  
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 5.4264E+008$   
 $M_{u1+} = 5.4264E+008$ , 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  
 $M_{u1-} = 5.4264E+008$ , 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

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 5.4264\text{E}+008$$

$M_{u2+} = 5.4264\text{E}+008$ , 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

$M_{u2-} = 5.4264\text{E}+008$ , 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  $M_{u1+}$

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

$$\phi_u = 4.1882964\text{E}-006$$

$$M_u = 5.4264\text{E}+008$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$\nu = 0.0015437$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_{cu}^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01151713$$

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

$$\text{From (5.4b), TB DY: } \phi_{cu} = 0.01151713$$

$$\text{we (5.4c)} = 0.04017143$$

$$\phi_{ase} ((5.4d), \text{TB DY}) = (\phi_{ase1} * A_{ext} + \phi_{ase2} * A_{int}) / A_{sec} = 0.53375773$$

$$\phi_{ase1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\phi_{ase2} (>= \phi_{ase1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$$

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$$

$$p_{sh1} ((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$$

$$L_{stir1} (\text{Length of stirrups along Y}) = 2160.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$p_{sh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$$

$$L_{stir2} (\text{Length of stirrups along Y}) = 1568.00$$

$$A_{stir2} (\text{stirrups area}) = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$$

$$p_{sh1} ((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$$

$$L_{stir1} (\text{Length of stirrups along X}) = 2560.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$psh2 ((5.4d), TBDY) = Lstir2 * Astir2 / (Asec * s2) = 0.00070345$   
 $Lstir2 (\text{Length of stirrups along X}) = 1968.00$   
 $Astir2 (\text{stirrups area}) = 50.26548$

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

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

lo/lou,min = lb/lb = 0.16198962

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

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

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

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

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 257.9541

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

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

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

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

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

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 257.9541

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

yv = 0.00092863

shv = 0.00297161

ftv = 309.5449

fyv = 257.9541

suv = 0.00297161

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

lo/lou,min = lb/lb = 0.16198962

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  $\text{Min}(1, 1.25 * (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 257.9541

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.02948185

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.02948185

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.06919209

and confined core properties:

b = 390.00

d = 877.00

$d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03518117$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.03518117$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08256805$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.21774786$   
 $Mu = MRc (4.14) = 5.4264E+008$   
 $u = su (4.1) = 4.1882964E-006$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.16198962$   
 $l_b = 300.00$   
 $l_d = 1851.971$   
 Calculation of  $l_b$ ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $l_d$ ,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 694.45$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$   
 $n = 30.00$

Calculation of  $Mu1$ -

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 4.1882964E-006$   
 $Mu = 5.4264E+008$

with full section properties:

$b = 450.00$   
 $d = 907.00$   
 $d' = 43.00$   
 $v = 0.0015437$   
 $N = 20792.022$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01151713$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01151713$   
 $we (5.4c) = 0.04017143$   
 $ase ((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53375773$   
 $ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)  
 "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max1 = 464100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
Aconf,min1 = 395025.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 173066.667 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.53375773$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 252164.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 111441.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 110709.333 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 2.48363$

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 2.48363  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.00301593$

Lstir1 (Length of stirrups along Y) = 2160.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00056047$

Lstir2 (Length of stirrups along Y) = 1568.00

Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 2.97078  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.00357443$

Lstir1 (Length of stirrups along X) = 2560.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00070345$

Lstir2 (Length of stirrups along X) = 1968.00

Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962

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

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.

with fs1 =  $(f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 257.9541$

with Es1 =  $(E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor



and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.16198962$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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  $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 257.9541$   
 with  $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.00092863$   
 $sh_v = 0.00297161$   
 $ft_v = 309.5449$   
 $fy_v = 257.9541$   
 $suv = 0.00297161$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.16198962$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $fs_v = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 257.9541$   
 with  $Es_v = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.02948185$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.02948185$   
 $v = Asl_{mid} / (b * d) * (fs_v / fc) = 0.06919209$

and confined core properties:

$b = 390.00$   
 $d = 877.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.03518117$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.03518117$   
 $v = Asl_{mid} / (b * d) * (fs_v / fc) = 0.08256805$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

---->

$su (4.9) = 0.21774786$

$Mu = MRc (4.14) = 5.4264E+008$

$u = su (4.1) = 4.1882964E-006$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.16198962$

$l_b = 300.00$

$l_d = 1851.971$

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

$l_{d,min}$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 694.45$

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.37392$

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

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 30.00$$

Calculation of  $\mu_{2+}$

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

$$\mu = 4.1882964\text{E-}006$$

$$\mu_{2+} = 5.4264\text{E+}008$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_{cu} = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01151713$$

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

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01151713$$

$$\text{we (5.4c) } = 0.04017143$$

$$\text{ase ((5.4d), TBDY) } = (\text{ase1} * A_{\text{ext}} + \text{ase2} * A_{\text{int}}) / A_{\text{sec}} = 0.53375773$$

$$\text{ase1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.53375773$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\text{ase2 } (>= \text{ase1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.53375773$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max2}} = 252164.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{\text{conf,min2}} = 111441.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{\text{conf,max2}}$  by a length equal to half the clear spacing between internal hoops.

$A_{\text{noConf2}} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\text{psh,min} * F_{ywe} = \text{Min}(\text{psh,x} * F_{ywe}, \text{psh,y} * F_{ywe}) = 2.48363$$

$$\text{psh}_x * F_{ywe} = \text{psh1} * F_{ywe1} + \text{ps2} * F_{ywe2} = 2.48363$$

$$\text{psh1 ((5.4d), TBDY) } = L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.00301593$$

$$L_{\text{stir1}} \text{ (Length of stirrups along Y) } = 2160.00$$

$$A_{\text{stir1}} \text{ (stirrups area) } = 78.53982$$

$$\text{psh2 (5.4d) } = L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00056047$$

$$L_{\text{stir2}} \text{ (Length of stirrups along Y) } = 1568.00$$

$$A_{\text{stir2}} \text{ (stirrups area) } = 50.26548$$

$$\text{psh}_y * F_{ywe} = \text{psh1} * F_{ywe1} + \text{ps2} * F_{ywe2} = 2.97078$$

$$\text{psh1 ((5.4d), TBDY) } = L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.00357443$$

$$L_{\text{stir1}} \text{ (Length of stirrups along X) } = 2560.00$$

$$A_{\text{stir1}} \text{ (stirrups area) } = 78.53982$$

$$\text{psh2 ((5.4d), TBDY) } = L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00070345$$

Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

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

lo/lou,min = lb/lb = 0.16198962

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 = 257.9541

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

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

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 = 257.9541

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

yv = 0.00092863

shv = 0.00297161

ftv = 309.5449

fyv = 257.9541

suv = 0.00297161

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

lo/lou,min = lb/lb = 0.16198962

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 = 257.9541

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.02948185

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.02948185

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.06919209

and confined core properties:

b = 390.00

d = 877.00

d' = 13.00

```

fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.03518117
2 = Asl,com/(b*d)*(fs2/fc) = 0.03518117
v = Asl,mid/(b*d)*(fsv/fc) = 0.08256805
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.21774786
Mu = MRc (4.14) = 5.4264E+008
u = su (4.1) = 4.1882964E-006

```

#### Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.16198962
lb = 300.00
ld = 1851.971
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
ld,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, 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 = 1.37392
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) = 250.00
n = 30.00

```

#### Calculation of Mu2-

```

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 4.1882964E-006
Mu = 5.4264E+008

```

#### with full section properties:

```

b = 450.00
d = 907.00
d' = 43.00
v = 0.0015437
N = 20792.022
fc = 33.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01151713
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01151713
we (5.4c) = 0.04017143
ase ((5.4d), TBDY) = (ase1*Aext+ase2*Aint)/Asec = 0.53375773
ase1 = Max(((Aconf,max1-AnoConf1)/Aconf,max1)*(Aconf,min1/Aconf,max1),0) = 0.53375773
The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization
of the rectangular sections confinement, which is expressed by (5.4d).
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)
"Theoretical Stress-Strain Model for Confined Concrete."
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

```

Aconf,max1 = 464100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
Aconf,min1 = 395025.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 173066.667 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.53375773$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 252164.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 111441.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 110709.333 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 2.48363$

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 2.48363  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.00301593$   
Lstir1 (Length of stirrups along Y) = 2160.00  
Astir1 (stirrups area) = 78.53982  
psh2 (5.4d) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00056047$   
Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 2.97078  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.00357443$   
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00070345$   
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

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

lo/lou,min =  $l_b/l_d = 0.16198962$

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

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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 257.9541$

with Es1 =  $(E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.02948185
2 = Asl,com/(b*d)*(fs2/fc) = 0.02948185
v = Asl,mid/(b*d)*(fsv/fc) = 0.06919209
and confined core properties:
b = 390.00
d = 877.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.03518117
2 = Asl,com/(b*d)*(fs2/fc) = 0.03518117
v = Asl,mid/(b*d)*(fsv/fc) = 0.08256805
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.21774786
Mu = MRc (4.14) = 5.4264E+008
u = su (4.1) = 4.1882964E-006
-----

Calculation of ratio lb/d
-----
Lap Length: lb/d = 0.16198962
lb = 300.00
ld = 1851.971
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
ld,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, 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 = 1.37392
Atr = Min(Atr_x,Atr_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  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$   
 $n = 30.00$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.6067\text{E}+006$

Calculation of Shear Strength at edge 1,  $V_{r1} = 1.6067\text{E}+006$

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

$V_{\text{ColO}} = 1.6067\text{E}+006$

$\text{knl} = 1$  (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:  $f'_c = (f'_{c\_jacket} * \text{Area}_{jacket} + f'_{c\_core} * \text{Area}_{core}) / \text{Area}_{\text{section}} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.04067$

$V_u = 1.3499588\text{E}-021$

$d = 0.8 * h = 760.00$

$N_u = 20792.022$

$A_g = 427500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 1.1114\text{E}+006$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 977392.20$

$V_{s,j1} = 314161.779$  is calculated for section web jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 1.00$

$s/d = 0.27777778$

$V_{s,j2} = 663230.422$  is calculated for section flange jacket, with:

$d = 760.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 1.00$

$s/d = 0.13157895$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 0.00$

$s/d = 1.25$

$V_{s,c2} = 134042.359$  is calculated for section flange core, with:

$d = 600.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 1.00$

$s/d = 0.41666667$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 0.00$

From (11-11), ACI 440:  $V_s + V_f \leq 1.3051\text{E}+006$

$b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.6067\text{E}+006$

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

$V_{\text{ColO}} = 1.6067\text{E}+006$

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

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

= 1 (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.04067$

$V_u = 1.3499588 \times 10^21$

$d = 0.8 \cdot h = 760.00$

$N_u = 20792.022$

$A_g = 427500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 1.1114 \times 10^6$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 977392.20$

$V_{s,j1} = 314161.779$  is calculated for section web jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 1.00$

$s/d = 0.27777778$

$V_{s,j2} = 663230.422$  is calculated for section flange jacket, with:

$d = 760.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 1.00$

$s/d = 0.13157895$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 134042.359$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 0.00$

$s/d = 1.25$

$V_{s,c2} = 134042.359$  is calculated for section flange core, with:

$d = 600.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 1.00$

$s/d = 0.41666667$

$V_f$  ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440:  $V_s + V_f \leq 1.3051 \times 10^6$

$b_w = 450.00$

End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\phi = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 450.00$   
 Max Width,  $W_{max} = 950.00$   
 Min Width,  $W_{min} = 450.00$   
 Eccentricity,  $Ecc = 250.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_b = 300.00$   
 No FRP Wrapping

#### Stepwise Properties

Bending Moment,  $M = -93929.214$   
 Shear Force,  $V_2 = 8018.608$   
 Shear Force,  $V_3 = -89.95386$   
 Axial Force,  $F = -21552.589$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $As_t = 0.00$   
   -Compression:  $As_c = 6691.592$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $As_{t,ten} = 1539.38$   
   -Compression:  $As_{c,com} = 2475.575$   
   -Middle:  $As_{mid} = 2676.637$   
 Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $As_{t,ten,jacket} = 1231.504$   
   -Compression:  $As_{c,com,jacket} = 1859.823$   
   -Middle:  $As_{mid,jacket} = 2060.885$   
 Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $As_{t,ten,core} = 307.8761$   
   -Compression:  $As_{c,com,core} = 615.7522$   
   -Middle:  $As_{mid,core} = 615.7522$   
 Mean Diameter of Tension Reinforcement,  $Db_L = 16.57143$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = 1.0^*$   $u = 0.00071869$   
 $u = y + p = 0.00071869$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00071869$  ((4.29), Biskinis Phd))  
 $M_y = 3.7889E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 1044.193  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.8350E+014$   
 $factor = 0.30$   
 $A_g = 562500.00$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$   
 $N = 21552.589$

$$E_c I_g = E_{c\_jacket} I_{g\_jacket} + E_{c\_core} I_{g\_core} = 6.1166E+014$$

Calculation of Yielding Moment  $M_y$

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

Assuming neutral axis within flange ( $\rho_y < t/d$ , compression zone rectangular) with:

flange width,  $b = 950.00$

web width,  $b_w = 450.00$

flange thickness,  $t = 450.00$

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

$$y_{\text{ten}} = 2.1200732E-006$$

$$\text{with } ((10.1), \text{ASCE 41-17}) f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / l_d)^{2/3}) = 239.4634$$

$$d = 707.00$$

$$y = 0.20119856$$

$$A = 0.01009692$$

$$B = 0.00476389$$

$$\text{with } p_t = 0.00229194$$

$$p_c = 0.00368581$$

$$p_v = 0.00398517$$

$$N = 21552.589$$

$$b = 950.00$$

$$\rho_y = 0.06082037$$

$$y_{\text{comp}} = 1.5661278E-005$$

$$\text{with } f_c = 33.00$$

$$E_c = 26999.444$$

$$y = 0.19869411$$

$$A = 0.00988999$$

$$B = 0.00462988$$

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

CONFIRMATION:  $\rho_y = 0.19955566 < t/d$

Calculation of ratio  $l_b / l_d$

$$\text{Lap Length: } l_d / l_{d,\text{min}} = 0.20248702$$

$$l_b = 300.00$$

$$l_d = 1481.576$$

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

$l_{d,\text{min}}$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (10.3.5, ASCE 41-17)

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 555.56$

Mean concrete strength:  $f'_c = (f'_{c\_jacket} * \text{Area}_{\text{jacket}} + f'_{c\_core} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.37392$$

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

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 30.00$$

- Calculation of  $\rho_p$  -

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

with:

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

$$\text{shear control ratio } V_y E / V_{col} E = 0.29138786$$

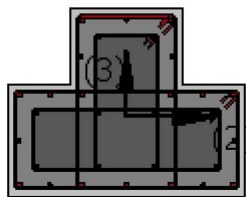
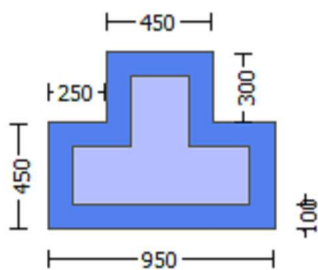
$$d = d_{\text{external}} = 707.00$$

$s = s_{\text{external}} = 0.00$   
 $t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.0035764$   
 jacket:  $s_1 = A_{v1} \cdot L_{\text{stir1}} / (s_1 \cdot A_g) = 0.00301593$   
 $A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction  
 $L_{\text{stir1}} = 2160.00$ , is the total Length of all stirrups parallel to loading (shear) direction  
 $s_1 = 100.00$   
 core:  $s_2 = A_{v2} \cdot L_{\text{stir2}} / (s_2 \cdot A_g) = 0.00056047$   
 $A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction  
 $L_{\text{stir2}} = 1568.00$ , is the total Length of all stirrups parallel to loading (shear) direction  
 $s_2 = 250.00$   
 The term  $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$  is implemented to account for FRP contribution  
 where  $f = 2 \cdot t_f / b_w$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength  
 All these variables have already been given in Shear control ratio calculation.  
 For the normalisation  $f_s$  of jacket is used.  
 $NUD = 21552.589$   
 $A_g = 562500.00$   
 $f_{cE} = (f_{c\_jacket} \cdot \text{Area\_jacket} + f_{c\_core} \cdot \text{Area\_core}) / \text{section\_area} = 33.00$   
 $f_{yE} = (f_{y\_ext\_Long\_Reinf} \cdot \text{Area\_ext\_Long\_Reinf} + f_{y\_int\_Long\_Reinf} \cdot \text{Area\_int\_Long\_Reinf}) / \text{Area\_Tot\_Long\_Rein} = 555.56$   
 $f_{yE} = (f_{y\_ext\_Trans\_Reinf} \cdot s_1 + f_{y\_int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 555.56$   
 $\rho_l = \text{Area\_Tot\_Long\_Rein} / (b \cdot d) = 0.00996292$   
 $b = 950.00$   
 $d = 707.00$   
 $f_{cE} = 33.00$

-----  
 End Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1  
 At local axis: 2  
 Integration Section: (b)  
 -----

## Calculation No. 7

column C1, Floor 1  
 Limit State: Operational Level (data interpolation between analysis steps 1 and 2)  
 Analysis: Uniform +X  
 Check: Shear capacity  $V_{Rd}$   
 Edge: End  
 Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JTC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Secondary 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

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

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

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $E_{cc} = 250.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = l_b = 300.00$

No FRP Wrapping

Stepwise Properties

EDGE -A-

Bending Moment,  $M_a = -175006.178$   
 Shear Force,  $V_a = 89.95386$   
 EDGE -B-  
 Bending Moment,  $M_b = -93929.214$   
 Shear Force,  $V_b = -89.95386$   
 BOTH EDGES  
 Axial Force,  $F = -21552.589$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{st} = 0.00$   
   -Compression:  $A_{sc} = 6691.592$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{st,ten} = 1539.38$   
   -Compression:  $A_{sc,com} = 2475.575$   
   -Middle:  $A_{sc,mid} = 2676.637$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.57143$

New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 1.1842E+006$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{ColO} = 1.1842E+006$   
 $V_{Col} = 1.1842E+006$   
 $k_n = 1.00$   
 displacement\_ductility\_demand =  $5.0637280E-007$

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:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 25.00$ , but  $f'_c^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $M_u = 93929.214$   
 $V_u = 89.95386$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 21552.589$   
 $A_g = 337500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 842449.486$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 753982.237$   
 $V_{s,j1} = 471238.898$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col_{j1} = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 282743.339$  is calculated for section flange jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col_{j2} = 1.00$   
 $s/d = 0.27777778$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 88467.249$   
 $V_{s,c1} = 88467.249$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 500.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col_{c1} = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 500.00$   
 $s = 250.00$

$V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.25$   
 $V_f((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 896810.169$   
 $bw = 450.00$

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

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

From analysis, chord rotation  $\theta = 3.6392531E-010$   
 $y = (M_y * L_s / 3) / E_{eff} = 0.00071869$  ((4.29), Biskinis Phd))  
 $M_y = 3.7889E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 1044.193  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.8350E+014$   
 $factor = 0.30$   
 $A_g = 562500.00$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$   
 $N = 21552.589$   
 $E_c * I_g = E_c * I_{g,jacket} + E_c * I_{g,core} = 6.1166E+014$

Calculation of Yielding Moment  $M_y$

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

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:  
 flange width,  $b = 950.00$   
 web width,  $bw = 450.00$   
 flange thickness,  $t = 450.00$

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 2.1200732E-006$   
 with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 239.4634$   
 $d = 707.00$   
 $y = 0.20119856$   
 $A = 0.01009692$   
 $B = 0.00476389$   
 with  $pt = 0.00229194$   
 $pc = 0.00368581$   
 $pv = 0.00398517$   
 $N = 21552.589$   
 $b = 950.00$   
 $" = 0.06082037$   
 $y_{comp} = 1.5661278E-005$   
 with  $f_c = 33.00$   
 $E_c = 26999.444$   
 $y = 0.19869411$   
 $A = 0.00988999$   
 $B = 0.00462988$   
 with  $E_s = 200000.00$   
 CONFIRMATION:  $y = 0.19955566 < t/d$

Calculation of ratio  $I_b / I_d$

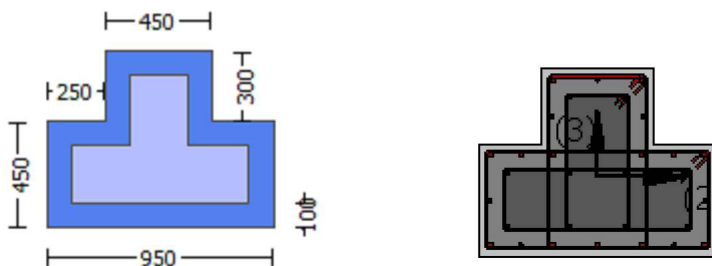
Lap Length:  $I_d / I_{d,min} = 0.20248702$   
 $I_b = 300.00$   
 $I_d = 1481.576$   
 Calculation of  $I$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $I_{d,min}$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (10.3.5, ASCE 41-17)  
 $= 1$

$db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 555.56$   
 Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$   
 where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$   
 $n = 30.00$

End Of Calculation of Shear Capacity for element: column JTC1 of floor 1  
 At local axis: 3  
 Integration Section: (b)

## Calculation No. 8

column C1, Floor 1  
 Limit State: Operational Level (data interpolation between analysis steps 1 and 2)  
 Analysis: Uniform +X  
 Check: Chord rotation capacity (  $\mu$  )  
 Edge: End  
 Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
 At Shear local axis: 3  
 (Bending local axis: 2)  
 Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:

```

Jacket
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$ 
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$ 
Concrete Elasticity,  $E_c = 26999.444$ 
Steel Elasticity,  $E_s = 200000.00$ 
Existing Column
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$ 
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$ 
Concrete Elasticity,  $E_c = 26999.444$ 
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
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$ 
#####
Max Height,  $H_{max} = 750.00$ 
Min Height,  $H_{min} = 450.00$ 
Max Width,  $W_{max} = 950.00$ 
Min Width,  $W_{min} = 450.00$ 
Eccentricity,  $Ecc = 250.00$ 
Jacket Thickness,  $t_j = 100.00$ 
Cover Thickness,  $c = 25.00$ 
Mean Confinement Factor overall section = 1.22443
Element Length,  $L = 3000.00$ 
Secondary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length  $l_o = 300.00$ 
No FRP Wrapping
-----

Stepwise Properties
-----
At local axis: 3
EDGE -A-
Shear Force,  $V_a = 4.6187021E-017$ 
EDGE -B-
Shear Force,  $V_b = -4.6187021E-017$ 
BOTH EDGES
Axial Force,  $F = -20792.022$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $As_t = 0.00$ 
-Compression:  $As_c = 6691.592$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension:  $As_{ten} = 1539.38$ 
-Compression:  $As_{com} = 2475.575$ 
-Middle:  $As_{mid} = 2676.637$ 
-----
-----

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.29138786$ 
Member Controlled by Flexure ( $V_e/V_r < 1$ )
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 386950.491$ 
with
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 5.8043E+008$ 
 $Mu_{1+} = 3.2937E+008$ , 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
 $Mu_{1-} = 5.8043E+008$ , 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
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 5.8043E+008$ 
 $Mu_{2+} = 3.2937E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction

```



which is defined for the the static loading combination

Mu2- = 5.8043E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu1+

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

$$\phi_u = 5.2477290E-006$$

$$M_u = 3.2937E+008$$

with full section properties:

$$b = 950.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$\nu = 0.00093808$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_o) = 0.01151713$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01151713$$

$$w_e \text{ (5.4c)} = 0.04017143$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53375773$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length

equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$$

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.48363$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2160.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1568.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.97078$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2560.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1968.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

```

Asec = 562500.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 694.45
fce = 33.00
From ((5.A.5), TBDY), TBDY: cc = 0.00424426
c = confinement factor = 1.22443
y1 = 0.00092863
sh1 = 0.00297161
ft1 = 309.5449
fy1 = 257.9541
su1 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 257.9541
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00092863
sh2 = 0.00297161
ft2 = 309.5449
fy2 = 257.9541
su2 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0179156
2 = Asl,com/(b*d)*(fs2/fc) = 0.02881122
v = Asl,mid/(b*d)*(fsv/fc) = 0.03115121
and confined core properties:
b = 890.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426

```

$c = \text{confinement factor} = 1.22443$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.01997081$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.03211633$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03472476$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su(4.9) = 0.19905879$   
 $Mu = MRc(4.14) = 3.2937E+008$   
 $u = su(4.1) = 5.2477290E-006$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.16198962$   
 $l_b = 300.00$   
 $l_d = 1851.971$   
 Calculation of  $l_b, \min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $l_d, \min$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 694.45$   
 Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}, A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \max(s_{external}, s_{internal}) = 250.00$   
 $n = 30.00$

Calculation of  $Mu1$ -

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 5.5327066E-006$   
 $Mu = 5.8043E+008$

with full section properties:

$b = 450.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00198039$   
 $N = 20792.022$   
 $f_c = 33.00$   
 $\alpha(5A.5, TBDY) = 0.002$   
 Final value of  $cu^*$ :  $cu^* = \text{shear\_factor} * \max(cu, cc) = 0.01151713$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01151713$   
 $w_e(5.4c) = 0.04017143$   
 $ase((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53375773$   
 $ase1 = \max(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 395025.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 173066.667 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.53375773$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 252164.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 111441.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 110709.333 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 2.48363$

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 2.48363  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00301593$   
Lstir1 (Length of stirrups along Y) = 2160.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d)) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00056047$   
Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 2.97078  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00357443$   
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00070345$   
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

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

lo/lou,min =  $l_b/l_d = 0.16198962$

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

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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,jacket} * A_{s1,ten,jacket} + f_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 257.9541$

with Es1 =  $(E_{s,jacket} * A_{s1,ten,jacket} + E_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 200000.00$

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

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

lo/lou,min =  $l_b/l_{b,min} = 0.16198962$

$su_2 = 0.4 \cdot esu_{2\_nominal} ((5.5), TBDY) = 0.032$   
 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  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 257.9541$   
 with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.00092863$   
 $sh_v = 0.00297161$   
 $ft_v = 309.5449$   
 $fy_v = 257.9541$   
 $suv = 0.00297161$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{u,min} = lb/ld = 0.16198962$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 257.9541$   
 with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.06082368$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.03782183$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.06576367$

and confined core properties:

$b = 390.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.07329111$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.04557442$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.07924369$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.24031351$

$\mu_u = MR_c (4.14) = 5.8043E+008$

$u = su (4.1) = 5.5327066E-006$

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

-----  
 Lap Length:  $lb/ld = 0.16198962$

$lb = 300.00$

$ld = 1851.971$

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

$ld_{min}$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 694.45$

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.37392$

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

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

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$$n = 30.00$$

Calculation of Mu2+

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

$$\mu = 5.2477290E-006$$

$$\mu = 3.2937E+008$$

with full section properties:

$$b = 950.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093808$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, c_o) = 0.01151713$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01151713$$

$$w_e \text{ (5.4c)} = 0.04017143$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53375773$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length

equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length

equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$$

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2160.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1568.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2560.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1968.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

```

Asec = 562500.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 694.45
fce = 33.00
From ((5A.5), TBDY), TBDY: cc = 0.00424426
c = confinement factor = 1.22443
y1 = 0.00092863
sh1 = 0.00297161
ft1 = 309.5449
fy1 = 257.9541
su1 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962
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 = 257.9541
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00092863
sh2 = 0.00297161
ft2 = 309.5449
fy2 = 257.9541
su2 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0179156
2 = Asl,com/(b*d)*(fs2/fc) = 0.02881122
v = Asl,mid/(b*d)*(fsv/fc) = 0.03115121
and confined core properties:
b = 890.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443

```

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.01997081$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.03211633$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03472476$$

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

---->

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

---->

$$s_u(4.9) = 0.19905879$$

$$M_u = M_{Rc}(4.14) = 3.2937E+008$$

$$u = s_u(4.1) = 5.2477290E-006$$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.16198962$

$$l_b = 300.00$$

$$l_d = 1851.971$$

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

$l_d$ ,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 694.45$

Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.37392$$

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

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

$$s = \max(s_{external}, s_{internal}) = 250.00$$

$$n = 30.00$$

Calculation of  $M_u2$ -

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

$$u = 5.5327066E-006$$

$$M_u = 5.8043E+008$$

with full section properties:

$$b = 450.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00198039$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \max(c_u, c_c) = 0.01151713$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01151713$$

$$\text{we (5.4c) } = 0.04017143$$

$$a_{se}((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53375773$$

$$a_{se1} = \max(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and



is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh,min * F_{ywe} = \text{Min}(psh,x * F_{ywe}, psh,y * F_{ywe}) = 2.48363$

-----  
 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$   
 $psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$   
 $L_{stir1}$  (Length of stirrups along Y) = 2160.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$   
 $L_{stir2}$  (Length of stirrups along Y) = 1568.00  
 $A_{stir2}$  (stirrups area) = 50.26548

-----  
 $psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$   
 $psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$   
 $L_{stir1}$  (Length of stirrups along X) = 2560.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$   
 $L_{stir2}$  (Length of stirrups along X) = 1968.00  
 $A_{stir2}$  (stirrups area) = 50.26548

-----  
 $A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00424426$

$c$  = confinement factor = 1.22443

$y1 = 0.00092863$

$sh1 = 0.00297161$

$ft1 = 309.5449$

$fy1 = 257.9541$

$su1 = 0.00297161$

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

Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.16198962$

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

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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 257.9541$

with  $Es1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y2 = 0.00092863$

$sh2 = 0.00297161$

$ft2 = 309.5449$

$fy2 = 257.9541$

$su2 = 0.00297161$

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

Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.16198962$

$su2 = 0.4 * esu2_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $es_{2\_nominal} = 0.08$ ,  
For calculation of  $es_{2\_nominal}$  and  $y_2$ ,  $sh_2$ ,  $ft_2$ ,  $fy_2$ , it is considered  
characteristic value  $fs_{y2} = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 257.9541$   
with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.00092863$   
 $sh_v = 0.00297161$   
 $ft_v = 309.5449$   
 $fy_v = 257.9541$   
 $suv = 0.00297161$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $lo/lo_{u,min} = lb/ld = 0.16198962$   
 $suv = 0.4 \cdot es_{uv\_nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $es_{uv\_nominal} = 0.08$ ,  
considering characteristic value  $fs_{yv} = fs_v/1.2$ , from table 5.1, TBDY  
For calculation of  $es_{uv\_nominal}$  and  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $fy_v$ , it is considered  
characteristic value  $fs_{yv} = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 257.9541$   
with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.06082368$   
 $2 = Asl_{com}/(b \cdot d) \cdot (fs_2/f_c) = 0.03782183$   
 $v = Asl_{mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.06576367$   
and confined core properties:  
 $b = 390.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = Asl_{ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.07329111$   
 $2 = Asl_{com}/(b \cdot d) \cdot (fs_2/f_c) = 0.04557442$   
 $v = Asl_{mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.07924369$   
Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)  
--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
--->  
 $su (4.9) = 0.24031351$   
 $Mu = MRc (4.14) = 5.8043E+008$   
 $u = su (4.1) = 5.5327066E-006$   
-----  
Calculation of ratio  $lb/ld$   
-----  
Lap Length:  $lb/ld = 0.16198962$   
 $lb = 300.00$   
 $ld = 1851.971$   
Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $ld_{min}$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
 $= 1$   
 $db = 16.66667$   
Mean strength value of all re-bars:  $fy = 694.45$   
Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $fc'^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$   
where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$   
 $n = 30.00$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.3280\text{E}+006$

Calculation of Shear Strength at edge 1,  $V_{r1} = 1.3280\text{E}+006$

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

$V_{\text{ColO}} = 1.3280\text{E}+006$

$\text{knl} = 1$  (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:  $f'_c = (f'_c_{\text{jacket}} * \text{Area}_{\text{jacket}} + f'_c_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1534.054$

$V_u = 4.6187021\text{E}-017$

$d = 0.8 * h = 600.00$

$N_u = 20792.022$

$A_g = 337500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 936062.473$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 837764.743$

$V_{s,j1} = 523602.964$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 1.00$

$s/d = 0.27777778$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 0.00$

$s/d = 1.25$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 0.00$

From (11-11), ACI 440:  $V_s + V_f \leq 1.0304\text{E}+006$

$b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.3280\text{E}+006$

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

$V_{\text{ColO}} = 1.3280\text{E}+006$

$\text{knl} = 1$  (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:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$ 
MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$ 
 $\mu_u = 1534.054$ 
 $V_u = 4.6187021E-017$ 
 $d = 0.8 \cdot h = 600.00$ 
 $N_u = 20792.022$ 
 $A_g = 337500.00$ 
From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 936062.473$ 
where:
 $V_{sjacket} = V_{sj1} + V_{sj2} = 837764.743$ 
 $V_{sj1} = 523602.964$  is calculated for section web jacket, with:
 $d = 600.00$ 
 $A_v = 157079.633$ 
 $f_y = 555.56$ 
 $s = 100.00$ 
 $V_{sj1}$  is multiplied by  $Col,j1 = 1.00$ 
 $s/d = 0.16666667$ 
 $V_{sj2} = 314161.779$  is calculated for section flange jacket, with:
 $d = 360.00$ 
 $A_v = 157079.633$ 
 $f_y = 555.56$ 
 $s = 100.00$ 
 $V_{sj2}$  is multiplied by  $Col,j2 = 1.00$ 
 $s/d = 0.27777778$ 
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$ 
 $V_{s,c1} = 98297.73$  is calculated for section web core, with:
 $d = 440.00$ 
 $A_v = 100530.965$ 
 $f_y = 555.56$ 
 $s = 250.00$ 
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$ 
 $s/d = 0.56818182$ 
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:
 $d = 200.00$ 
 $A_v = 100530.965$ 
 $f_y = 555.56$ 
 $s = 250.00$ 
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$ 
 $s/d = 1.25$ 
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$ 
From (11-11), ACI 440:  $V_s + V_f \leq 1.0304E+006$ 
 $bw = 450.00$ 
-----

```

```

-----
End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1
At local axis: 3
-----

```

```

-----
Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcjtcs

```

```

Constant Properties
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```

```

Knowledge Factor,  $\phi = 1.00$ 
Mean strength values are used for both shear and moment calculations.
Consequently:
Jacket
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$ 
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$ 
Concrete Elasticity,  $E_c = 26999.444$ 

```

Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 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  
 New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 450.00$   
 Max Width,  $W_{max} = 950.00$   
 Min Width,  $W_{min} = 450.00$   
 Eccentricity,  $E_{cc} = 250.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.22443  
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_o = 300.00$   
 No FRP Wrapping

#### Stepwise Properties

At local axis: 2  
 EDGE -A-  
 Shear Force,  $V_a = 1.3499588E-021$   
 EDGE -B-  
 Shear Force,  $V_b = -1.3499588E-021$   
 BOTH EDGES  
 Axial Force,  $F = -20792.022$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $A_{slt} = 0.00$   
 -Compression:  $A_{slc} = 6691.592$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $A_{sl,ten} = 1539.38$   
 -Compression:  $A_{sl,com} = 1539.38$   
 -Middle:  $A_{sl,mid} = 3612.832$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.22515134$   
 Member Controlled by Flexure ( $V_e/V_r < 1$ )  
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 361758.676$   
 with  
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 5.4264E+008$   
 $\mu_{u1+} = 5.4264E+008$ , 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  
 $\mu_{u1-} = 5.4264E+008$ , 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  
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 5.4264E+008$   
 $\mu_{u2+} = 5.4264E+008$ , 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  
 $\mu_{u2-} = 5.4264E+008$ , 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:

$$u = 4.1882964E-006$$

$$Mu = 5.4264E+008$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } cu: cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01151713$$

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

$$\text{From (5.4b), TBDY: } cu = 0.01151713$$

$$we(5.4c) = 0.04017143$$

$$ase((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53375773$$

$$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$$

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$$

$$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$$

$$L_{stir1} (\text{Length of stirrups along Y}) = 2160.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$psh2(5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$$

$$L_{stir2} (\text{Length of stirrups along Y}) = 1568.00$$

$$A_{stir2} (\text{stirrups area}) = 50.26548$$

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$$

$$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$$

$$L_{stir1} (\text{Length of stirrups along X}) = 2560.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$psh2((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$$

$$L_{stir2} (\text{Length of stirrups along X}) = 1968.00$$

$$A_{stir2} (\text{stirrups area}) = 50.26548$$

$$A_{sec} = 562500.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$fy_{we1} = 694.45$   
 $fy_{we2} = 694.45$   
 $f_{ce} = 33.00$   
 From ((5.A.5), TBDY), TBDY:  $cc = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $y_1 = 0.00092863$   
 $sh_1 = 0.00297161$   
 $ft_1 = 309.5449$   
 $fy_1 = 257.9541$   
 $su_1 = 0.00297161$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou, min = lb/ld = 0.16198962$   
 $su_1 = 0.4 * esu_1, nominal ((5.5), TBDY) = 0.032$   
 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  $fs_1 = (fs_{jacket} * Asl, ten, jacket + fs_{core} * Asl, ten, core) / Asl, ten = 257.9541$   
 with  $Es_1 = (Es_{jacket} * Asl, ten, jacket + Es_{core} * Asl, ten, core) / Asl, ten = 200000.00$   
 $y_2 = 0.00092863$   
 $sh_2 = 0.00297161$   
 $ft_2 = 309.5449$   
 $fy_2 = 257.9541$   
 $su_2 = 0.00297161$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou, min = lb/lb, min = 0.16198962$   
 $su_2 = 0.4 * esu_2, nominal ((5.5), TBDY) = 0.032$   
 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  $fs_2 = (fs_{jacket} * Asl, com, jacket + fs_{core} * Asl, com, core) / Asl, com = 257.9541$   
 with  $Es_2 = (Es_{jacket} * Asl, com, jacket + Es_{core} * Asl, com, core) / Asl, com = 200000.00$   
 $y_v = 0.00092863$   
 $sh_v = 0.00297161$   
 $ft_v = 309.5449$   
 $fy_v = 257.9541$   
 $suv = 0.00297161$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou, min = lb/ld = 0.16198962$   
 $suv = 0.4 * esuv, nominal ((5.5), TBDY) = 0.032$   
 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  $fsv = (fs_{jacket} * Asl, mid, jacket + fs_{mid} * Asl, mid, core) / Asl, mid = 257.9541$   
 with  $Es_v = (Es_{jacket} * Asl, mid, jacket + Es_{mid} * Asl, mid, core) / Asl, mid = 200000.00$   
 $1 = Asl, ten / (b * d) * (fs_1 / f_c) = 0.02948185$   
 $2 = Asl, com / (b * d) * (fs_2 / f_c) = 0.02948185$   
 $v = Asl, mid / (b * d) * (fsv / f_c) = 0.06919209$   
 and confined core properties:  
 $b = 390.00$   
 $d = 877.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = Asl, ten / (b * d) * (fs_1 / f_c) = 0.03518117$   
 $2 = Asl, com / (b * d) * (fs_2 / f_c) = 0.03518117$   
 $v = Asl, mid / (b * d) * (fsv / f_c) = 0.08256805$

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

--->  
v < vs,y2 - LHS eq.(4.5) is satisfied  
--->  
su (4.9) = 0.21774786  
Mu = MRc (4.14) = 5.4264E+008  
u = su (4.1) = 4.1882964E-006

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

Lap Length: lb/l<sub>d</sub> = 0.16198962  
lb = 300.00  
l<sub>d</sub> = 1851.971  
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
l<sub>d,min</sub> from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
= 1  
db = 16.66667  
Mean strength value of all re-bars: fy = 694.45  
Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 33.00, 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<sub>tr</sub> = 1.37392  
A<sub>tr</sub> = Min(A<sub>tr\_x</sub>, A<sub>tr\_y</sub>) = 257.6106  
where A<sub>tr\_x</sub>, A<sub>tr\_y</sub> are the sum of the area of all stirrup legs along X and Y loxal axis  
s = Max(s\_external, s\_internal) = 250.00  
n = 30.00

Calculation of Mu1-

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

u = 4.1882964E-006  
Mu = 5.4264E+008

with full section properties:

b = 450.00  
d = 907.00  
d' = 43.00  
v = 0.0015437  
N = 20792.022  
fc = 33.00  
co (5A.5, TBDY) = 0.002  
Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01151713  
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY: cu = 0.01151713  
we (5.4c) = 0.04017143  
ase ((5.4d), TBDY) = (ase1\*Aext+ase2\*Aint)/Asec = 0.53375773  
ase1 = Max(((Aconf,max1-AnoConf1)/Aconf,max1)\*(Aconf,min1/Aconf,max1),0) = 0.53375773  
The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
Aconf,max1 = 464100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
Aconf,min1 = 395025.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.  
AnoConf1 = 173066.667 is the unconfined external core area which is equal to bi<sup>2</sup>/6 as defined at (A.2).



$$ase2 (>=ase1) = \text{Max}(((A_{conf,max2}-A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh,min * F_{ywe} = \text{Min}(psh,x * F_{ywe}, psh,y * F_{ywe}) = 2.48363$

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

$$psh2 \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

$A_{stir1}$  (stirrups area) = 78.53982

$$psh2 \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

$A_{stir2}$  (stirrups area) = 50.26548

$$A_{sec} = 562500.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 694.45$$

$$f_{ce} = 33.00$$

From ((5.A5), TBDY), TBDY:  $cc = 0.00424426$

$c$  = confinement factor = 1.22443

$$y1 = 0.00092863$$

$$sh1 = 0.00297161$$

$$ft1 = 309.5449$$

$$fy1 = 257.9541$$

$$su1 = 0.00297161$$

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

$$l_o/l_{ou,min} = l_b/l_d = 0.16198962$$

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

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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 257.9541$$

$$\text{with } Es1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$$

$$y2 = 0.00092863$$

$$sh2 = 0.00297161$$

$$ft2 = 309.5449$$

$$fy2 = 257.9541$$

$$su2 = 0.00297161$$

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

$$l_o/l_{ou,min} = l_b/l_{b,min} = 0.16198962$$

$$su2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

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  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs2 = (fs_{jacket} \cdot A_{sl,com,jacket} + fs_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 257.9541$   
 with  $Es2 = (Es_{jacket} \cdot A_{sl,com,jacket} + Es_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 200000.00$   
 $yv = 0.00092863$   
 $shv = 0.00297161$   
 $ftv = 309.5449$   
 $fyv = 257.9541$   
 $suv = 0.00297161$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/ld = 0.16198962$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $fsv = (fs_{jacket} \cdot A_{sl,mid,jacket} + fs_{mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 257.9541$   
 with  $Esv = (Es_{jacket} \cdot A_{sl,mid,jacket} + Es_{mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b \cdot d) \cdot (fs1 / fc) = 0.02948185$   
 $2 = A_{sl,com} / (b \cdot d) \cdot (fs2 / fc) = 0.02948185$   
 $v = A_{sl,mid} / (b \cdot d) \cdot (fsv / fc) = 0.06919209$   
 and confined core properties:  
 $b = 390.00$   
 $d = 877.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = A_{sl,ten} / (b \cdot d) \cdot (fs1 / fc) = 0.03518117$   
 $2 = A_{sl,com} / (b \cdot d) \cdot (fs2 / fc) = 0.03518117$   
 $v = A_{sl,mid} / (b \cdot d) \cdot (fsv / fc) = 0.08256805$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < vs,y2$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.21774786$   
 $Mu = MRc (4.14) = 5.4264E+008$   
 $u = su (4.1) = 4.1882964E-006$   
 -----  
 Calculation of ratio  $lb/ld$   
 -----  
 Lap Length:  $lb/ld = 0.16198962$   
 $lb = 300.00$   
 $ld = 1851.971$   
 Calculation of  $lb,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $ld,min$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $fy = 694.45$   
 Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $fc'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $Ktr = 1.37392$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$   
 $n = 30.00$   
 -----  
 -----  
 -----

## Calculation of Mu2+

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

$$\phi_u = 4.1882964E-006$$

$$M_u = 5.4264E+008$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_{cu}: \phi_{cu}^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{co}) = 0.01151713$$

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

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01151713$$

$$\phi_{we} (5.4c) = 0.04017143$$

$$\phi_{ase} ((5.4d), TBDY) = (\phi_{ase1} * A_{ext} + \phi_{ase2} * A_{int}) / A_{sec} = 0.53375773$$

$$\phi_{ase1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\phi_{ase2} (> \phi_{ase1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\phi_{psh,min} * F_{ywe} = \text{Min}(\phi_{psh,x} * F_{ywe}, \phi_{psh,y} * F_{ywe}) = 2.48363$$

$$\phi_{psh,x} * F_{ywe} = \phi_{psh1} * F_{ywe1} + \phi_{ps2} * F_{ywe2} = 2.48363$$

$$\phi_{psh1} ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2160.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$\phi_{psh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1568.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$\phi_{psh,y} * F_{ywe} = \phi_{psh1} * F_{ywe1} + \phi_{ps2} * F_{ywe2} = 2.97078$$

$$\phi_{psh1} ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2560.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$\phi_{psh2} ((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1968.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$A_{sec} = 562500.00$$

$$s_1 = 100.00$$

$$s_2 = 250.00$$

$$f_{ywe1} = 694.45$$

```

fywe2 = 694.45
fce = 33.00
From ((5A.5), TBDY), TBDY: cc = 0.00424426
c = confinement factor = 1.22443
y1 = 0.00092863
sh1 = 0.00297161
ft1 = 309.5449
fy1 = 257.9541
su1 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 257.9541
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00092863
sh2 = 0.00297161
ft2 = 309.5449
fy2 = 257.9541
su2 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.02948185
2 = Asl,com/(b*d)*(fs2/fc) = 0.02948185
v = Asl,mid/(b*d)*(fsv/fc) = 0.06919209
and confined core properties:
b = 390.00
d = 877.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.03518117
2 = Asl,com/(b*d)*(fs2/fc) = 0.03518117
v = Asl,mid/(b*d)*(fsv/fc) = 0.08256805
Case/Assumption: Unconfinedsd full section - Steel rupture

```

satisfies Eq. (4.3)

--->

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

--->

$\mu_u$  (4.9) = 0.21774786

$\mu_u = M_{Rc}$  (4.14) = 5.4264E+008

$u = \mu_u$  (4.1) = 4.1882964E-006

Calculation of ratio  $I_b/I_d$

Lap Length:  $I_b/I_d = 0.16198962$

$I_b = 300.00$

$I_d = 1851.971$

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

$I_d$ ,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

= 1

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 694.45$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$

MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.37392$

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

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

$s = \max(s_{external}, s_{internal}) = 250.00$

$n = 30.00$

Calculation of  $\mu_u$ -

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

$u = 4.1882964E-006$

$\mu_u = 5.4264E+008$

with full section properties:

$b = 450.00$

$d = 907.00$

$d' = 43.00$

$v = 0.0015437$

$N = 20792.022$

$f'_c = 33.00$

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

Final value of  $\phi$ :  $\phi^* = \text{shear\_factor} \cdot \max(\phi, \phi_c) = 0.01151713$

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

From (5.4b), TBDY:  $\phi = 0.01151713$

we (5.4c) = 0.04017143

$\phi_{se}$  ((5.4d), TBDY) =  $(\phi_{se1} \cdot A_{ext} + \phi_{se2} \cdot A_{int}) / A_{sec} = 0.53375773$

$\phi_{se1} = \max((A_{conf,max1} - A_{noConf1}) / A_{conf,max1} \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\phi_{se2} (\geq \phi_{se1}) = \max(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) \cdot (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 252164.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 111441.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 110709.333 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 2.48363

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 2.48363

psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00301593

Lstir1 (Length of stirrups along Y) = 2160.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) = Lstir2\*Astir2/(Asec\*s2) = 0.00056047

Lstir2 (Length of stirrups along Y) = 1568.00

Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 2.97078

psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00357443

Lstir1 (Length of stirrups along X) = 2560.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) = Lstir2\*Astir2/(Asec\*s2) = 0.00070345

Lstir2 (Length of stirrups along X) = 1968.00

Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

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

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

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

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 257.9541

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

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

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  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 257.9541$   
 with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.00092863$   
 $sh_v = 0.00297161$   
 $ft_v = 309.5449$   
 $fy_v = 257.9541$   
 $suv = 0.00297161$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/ld = 0.16198962$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 257.9541$   
 with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.02948185$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.02948185$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.06919209$

and confined core properties:

$b = 390.00$   
 $d = 877.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.03518117$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.03518117$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.08256805$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.21774786$   
 $Mu = MRc (4.14) = 5.4264E+008$   
 $u = su (4.1) = 4.1882964E-006$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.16198962$

$lb = 300.00$

$ld = 1851.971$

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

$ld,min$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 694.45$

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.37392$

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

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

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 30.00$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.6067\text{E}+006$

Calculation of Shear Strength at edge 1,  $V_{r1} = 1.6067\text{E}+006$

$V_{r1} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{\text{Col}0}$

$V_{\text{Col}0} = 1.6067\text{E}+006$

$k_{nl} = 1$  (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:  $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.04067$

$\nu_u = 1.3499588\text{E}-021$

$d = 0.8 * h = 760.00$

$N_u = 20792.022$

$A_g = 427500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 1.1114\text{E}+006$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 977392.20$

$V_{s,j1} = 314161.779$  is calculated for section web jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 1.00$

$s/d = 0.27777778$

$V_{s,j2} = 663230.422$  is calculated for section flange jacket, with:

$d = 760.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 1.00$

$s/d = 0.13157895$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 134042.359$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 0.00$

$s/d = 1.25$

$V_{s,c2} = 134042.359$  is calculated for section flange core, with:

$d = 600.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 1.00$

$s/d = 0.41666667$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 0.00$

From (11-11), ACI 440:  $V_s + V_f \leq 1.3051\text{E}+006$

$b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.6067\text{E}+006$

$V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{\text{Col}0}$

$V_{\text{Col}0} = 1.6067\text{E}+006$

$k_{nl} = 1$  (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:  $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)



$M/Vd = 2.00$   
 $\mu_u = 1.04067$   
 $V_u = 1.3499588E-021$   
 $d = 0.8 \cdot h = 760.00$   
 $N_u = 20792.022$   
 $A_g = 427500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 1.1114E+006$   
 where:  
 $V_{sjacket} = V_{sj1} + V_{sj2} = 977392.20$   
 $V_{sj1} = 314161.779$  is calculated for section web jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{sj1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.27777778$   
 $V_{sj2} = 663230.422$  is calculated for section flange jacket, with:  
 $d = 760.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{sj2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.13157895$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.25$   
 $V_{s,c2} = 134042.359$  is calculated for section flange core, with:  
 $d = 600.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.41666667$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 1.3051E+006$   
 $bw = 450.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
 At local axis: 2  
 -----

-----  
 Start Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1  
 At local axis: 3  
 Integration Section: (b)  
 Section Type: rcjtcs

Constant Properties

-----  
 Knowledge Factor,  $\phi = 1.00$   
 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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 450.00$   
Max Width,  $W_{max} = 950.00$   
Min Width,  $W_{min} = 450.00$   
Eccentricity,  $Ecc = 250.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Secondary Member  
Smooth Bars  
Ductile Steel  
With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_b = 300.00$   
No FRP Wrapping

#### Stepwise Properties

Bending Moment,  $M = 173791.562$   
Shear Force,  $V_2 = 8018.608$   
Shear Force,  $V_3 = -89.95386$   
Axial Force,  $F = -21552.589$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten} = 1539.38$   
-Compression:  $A_{st,com} = 1539.38$   
-Middle:  $A_{st,mid} = 3612.832$   
Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten,jacket} = 1231.504$   
-Compression:  $A_{st,com,jacket} = 1231.504$   
-Middle:  $A_{st,mid,jacket} = 2689.203$   
Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten,core} = 307.8761$   
-Compression:  $A_{st,com,core} = 307.8761$   
-Middle:  $A_{st,mid,core} = 923.6282$   
Mean Diameter of Tension Reinforcement,  $D_{bL} = 16.57143$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $\phi_{u,R} = 1.0^*$   $\phi_u = 0.00018667$   
 $\phi_u = \phi_y + \phi_p = 0.00018667$

- Calculation of  $\phi_y$  -

$\phi_y = (M_y * L_s / 3) / E_{eff} = 0.00018667$  ((4.29), Biskinis Phd))  
 $M_y = 5.2059E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) =  $300.00$   
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.7887E+014$   
factor =  $0.30$   
 $A_g = 562500.00$   
Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$   
 $N = 21552.589$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 9.2958E+014$

Calculation of Yielding Moment  $M_y$

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

```

y = Min( y_ten, y_com)
y_ten = 1.7803416E-006
with ((10.1), ASCE 41-17) fy = Min(fy, 1.25*fy*(lb/d)^ 2/3) = 239.4634
d = 907.00
y = 0.25852163
A = 0.01661545
B = 0.00880662
with pt = 0.0037716
pc = 0.0037716
pv = 0.00885172
N = 21552.589
b = 450.00
" = 0.04740904
y_comp = 9.4779300E-006
with fc = 33.00
Ec = 26999.444
y = 0.25592389
A = 0.01627492
B = 0.0085861
with Es = 200000.00

```

#### Calculation of ratio lb/d

```

Lap Length: ld/d,min = 0.20248702
lb = 300.00
ld = 1481.576
Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
ld,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (10.3.5, ASCE 41-17)
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 555.56
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, 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 = 1.37392
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) = 250.00
n = 30.00

```

#### - Calculation of p -

```

From table 10-8: p = 0.00
with:
- Columns controlled by inadequate development or splicing along the clear height because lb/d < 1
shear control ratio VyE/VColOE = 0.22515134
d = d_external = 907.00
s = s_external = 0.00
- t = s1 + s2 + 2*tf/bw*(ffe/fs) = 0.00427788
jacket: s1 = Av1*Lstir1/(s1*Ag) = 0.00357443
Av1 = 78.53982, is the area of every stirrup parallel to loading (shear) direction
Lstir1 = 2560.00, is the total Length of all stirrups parallel to loading (shear) direction
s1 = 100.00
core: s2 = Av2*Lstir2/(s2*Ag) = 0.00070345
Av2 = 50.26548, is the area of every stirrup parallel to loading (shear) direction
Lstir2 = 1968.00, is the total Length of all stirrups parallel to loading (shear) direction
s2 = 250.00
The term 2*tf/bw*(ffe/fs) is implemented to account for FRP contribution
where f = 2*tf/bw is FRP ratio (EC8 - 3, A.4.4.3(6)) and ffe/fs normalises f to steel strength
All these variables have already been given in Shear control ratio calculation.

```

For the normalisation  $f_s$  of jacket is used.

$$NUD = 21552.589$$

$$A_g = 562500.00$$

$$f_{cE} = (f_{c\_jacket} \cdot Area\_jacket + f_{c\_core} \cdot Area\_core) / section\_area = 33.00$$

$$f_{yE} = (f_{y\_ext\_Long\_Reinf} \cdot Area\_ext\_Long\_Reinf + f_{y\_int\_Long\_Reinf} \cdot Area\_int\_Long\_Reinf) / Area\_Tot\_Long\_Rein = 555.56$$

$$f_{yE} = (f_{y\_ext\_Trans\_Reinf} \cdot s_1 + f_{y\_int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 555.56$$

$$\rho_l = Area\_Tot\_Long\_Rein / (b \cdot d) = 0.01639493$$

$$b = 450.00$$

$$d = 907.00$$

$$f_{cE} = 33.00$$

End Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1

At local axis: 3

Integration Section: (b)

## Calculation No. 9

column C1, Floor 1

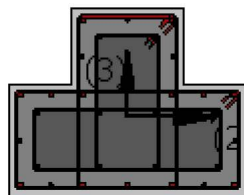
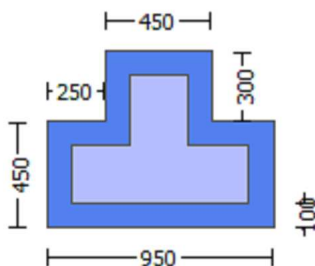
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JTC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Secondary 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

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

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

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $E_{cc} = 250.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = l_b = 300.00$

No FRP Wrapping

#### Stepwise Properties

EDGE -A-

Bending Moment,  $M_a = -2.9148E+007$

Shear Force,  $V_a = -9644.583$

EDGE -B-

Bending Moment,  $M_b = 209031.971$

Shear Force,  $V_b = 9644.583$

BOTH EDGES

Axial Force,  $F = -21706.813$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $A_{sc} = 6691.592$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{st,ten} = 1539.38$

-Compression:  $A_{st,com} = 1539.38$

-Middle:  $A_{st,mid} = 3612.832$

Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.57143$

New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 1.2175E+006$

$V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{CoIO} = 1.2175E+006$

$V_{CoI} = 1.2175E+006$

$k_n = 1.00$

displacement\_ductility\_demand = 0.03313665

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:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 25.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 3.97662$

$\mu_u = 2.9148 \times 10^7$

$V_u = 9644.583$

$d = 0.8 \cdot h = 760.00$

$N_u = 21706.813$

$A_g = 427500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 1.0003 \times 10^6$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 879645.943$

$V_{s,j1} = 282743.339$  is calculated for section web jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 1.00$

$s/d = 0.27777778$

$V_{s,j2} = 596902.604$  is calculated for section flange jacket, with:

$d = 760.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 1.00$

$s/d = 0.13157895$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 120637.158$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 500.00$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 0.00$

$s/d = 1.25$

$V_{s,c2} = 120637.158$  is calculated for section flange core, with:

$d = 600.00$

$A_v = 100530.965$

$f_y = 500.00$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 1.00$

$s/d = 0.41666667$

$V_f$  ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440:  $V_s + V_f \leq 1.1360 \times 10^6$

$b_w = 450.00$

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  $\theta = 6.2322241 \times 10^{-5}$

$y = (M_y \cdot L_s / 3) / \text{Eleff} = 0.00188076$  ((4.29), Biskinis Phd)

$M_y = 5.2064 \times 10^8$

$L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 3022.232

From table 10.5, ASCE 41\_17:  $\text{Eleff} = \text{factor} \cdot E_c \cdot I_g = 2.7887 \times 10^{14}$

factor = 0.30

$A_g = 562500.00$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$

$N = 21706.813$

$E_c \cdot I_g = E_{c,\text{jacket}} \cdot I_{g,\text{jacket}} + E_{c,\text{core}} \cdot I_{g,\text{core}} = 9.2958 \times 10^{14}$

Calculation of Yielding Moment  $M_y$

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

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$   
 $y_{\text{ten}} = 1.7803962\text{E-}006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 239.4634$   
 $d = 907.00$   
 $y = 0.25854434$   
 $A = 0.01661703$   
 $B = 0.0088082$   
with  $p_t = 0.0037716$   
 $p_c = 0.0037716$   
 $p_v = 0.00885172$   
 $N = 21706.813$   
 $b = 450.00$   
 $" = 0.04740904$   
 $y_{\text{comp}} = 9.4777698\text{E-}006$   
with  $f_c = 33.00$   
 $E_c = 26999.444$   
 $y = 0.25592822$   
 $A = 0.01627407$   
 $B = 0.0085861$   
with  $E_s = 200000.00$

Calculation of ratio  $l_b/d$

Lap Length:  $l_d/d, \text{min} = 0.20248702$   
 $l_b = 300.00$   
 $l_d = 1481.576$   
Calculation of  $l$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $l_d, \text{min}$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (10.3.5, ASCE 41-17)  
 $= 1$   
 $db = 16.66667$   
Mean strength value of all re-bars:  $f_y = 555.56$   
Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$   
where  $A_{tr\_x}, A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$   
 $n = 30.00$

End Of Calculation of Shear Capacity for element: column JTC1 of floor 1

At local axis: 2

Integration Section: (a)

**Calculation No. 10**

column C1, Floor 1

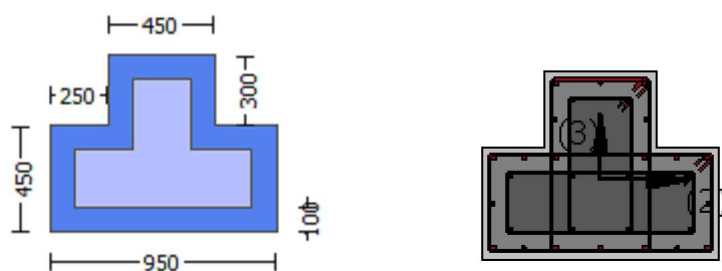
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $E_{cc} = 250.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.22443

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars



Ductile Steel  
With Detailing for Earthquake Resistance (including stirrups closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = 300.00$   
No FRP Wrapping

#### Stepwise Properties

At local axis: 3  
EDGE -A-  
Shear Force,  $V_a = 4.6187021E-017$   
EDGE -B-  
Shear Force,  $V_b = -4.6187021E-017$   
BOTH EDGES  
Axial Force,  $F = -20792.022$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{ten} = 1539.38$   
-Compression:  $As_{com} = 2475.575$   
-Middle:  $As_{mid} = 2676.637$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.29138786$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 386950.491$   
with  
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 5.8043E+008$   
 $Mu_{1+} = 3.2937E+008$ , 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  
 $Mu_{1-} = 5.8043E+008$ , 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  
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 5.8043E+008$   
 $Mu_{2+} = 3.2937E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination  
 $Mu_{2-} = 5.8043E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

#### Calculation of $Mu_{1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\phi_u = 5.2477290E-006$   
 $Mu = 3.2937E+008$

with full section properties:

$b = 950.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00093808$   
 $N = 20792.022$   
 $f_c = 33.00$   
 $\phi_c (5A.5, TBDY) = 0.002$   
Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01151713$   
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY:  $\phi_u = 0.01151713$   
 $\phi_{we} (5.4c) = 0.04017143$   
 $\phi_{ase} ((5.4d), TBDY) = (\phi_{ase1} * A_{ext} + \phi_{ase2} * A_{int}) / A_{sec} = 0.53375773$   
 $\phi_{ase1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$   
The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$

$psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$

$psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 ((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00424426$

$c = \text{confinement factor} = 1.22443$

$y1 = 0.00092863$

$sh1 = 0.00297161$

$ft1 = 309.5449$

$fy1 = 257.9541$

$su1 = 0.00297161$

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

$l_o/l_{ou,min} = l_b/l_d = 0.16198962$

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

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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 257.9541$

with  $Es1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y2 = 0.00092863$

$sh2 = 0.00297161$

$ft2 = 309.5449$

$fy2 = 257.9541$

```

su2 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0179156
2 = Asl,com/(b*d)*(fs2/fc) = 0.02881122
v = Asl,mid/(b*d)*(fsv/fc) = 0.03115121

```

and confined core properties:

```

b = 890.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.01997081
2 = Asl,com/(b*d)*(fs2/fc) = 0.03211633
v = Asl,mid/(b*d)*(fsv/fc) = 0.03472476

```

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

```

---->
v < vs,y2 - LHS eq.(4.5) is satisfied
---->
su (4.9) = 0.19905879
Mu = MRc (4.14) = 3.2937E+008
u = su (4.1) = 5.2477290E-006

```

Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.16198962
lb = 300.00
lb = 1851.971
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
lb,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, but fc'^0.5 <= 8.3
MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00

```

$cb = 25.00$   
 $Ktr = 1.37392$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$   
 $n = 30.00$

Calculation of  $Mu1$ -

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

$u = 5.5327066E-006$   
 $Mu = 5.8043E+008$

with full section properties:

$b = 450.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00198039$   
 $N = 20792.022$   
 $fc = 33.00$   
 $co(5A.5, TBDY) = 0.002$

Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01151713$

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

From (5.4b), TBDY:  $cu = 0.01151713$

we (5.4c) = 0.04017143

$ase((5.4d), TBDY) = (ase1 * Aext + ase2 * Aint) / Asec = 0.53375773$

$ase1 = \text{Max}(((Aconf, \text{max}1 - AnoConf1) / Aconf, \text{max}1) * (Aconf, \text{min}1 / Aconf, \text{max}1), 0) = 0.53375773$

The definitions of  $AnoConf$ ,  $Aconf, \text{min}$  and  $Aconf, \text{max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$Aconf, \text{max}1 = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$Aconf, \text{min}1 = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $Aconf, \text{max}1$  by a length equal to half the clear spacing between external hoops.

$AnoConf1 = 173066.667$  is the unconfined external core area which is equal to  $bi^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((Aconf, \text{max}2 - AnoConf2) / Aconf, \text{max}2) * (Aconf, \text{min}2 / Aconf, \text{max}2), 0) = 0.53375773$

The definitions of  $AnoConf$ ,  $Aconf, \text{min}$  and  $Aconf, \text{max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$Aconf, \text{max}2 = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$Aconf, \text{min}2 = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $Aconf, \text{max}2$  by a length equal to half the clear spacing between internal hoops.

$AnoConf2 = 110709.333$  is the unconfined internal core area which is equal to  $bi^2/6$  as defined at (A.2).

$psh, \text{min} * Fywe = \text{Min}(psh, x * Fywe, psh, y * Fywe) = 2.48363$

$psh, x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.48363$

$psh1((5.4d), TBDY) = Lstir1 * Astir1 / (Asec * s1) = 0.00301593$

$Lstir1$  (Length of stirrups along Y) = 2160.00

$Astir1$  (stirrups area) = 78.53982

$psh2(5.4d) = Lstir2 * Astir2 / (Asec * s2) = 0.00056047$

$Lstir2$  (Length of stirrups along Y) = 1568.00

$Astir2$  (stirrups area) = 50.26548

$psh, y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.97078$

$psh1((5.4d), TBDY) = Lstir1 * Astir1 / (Asec * s1) = 0.00357443$

$Lstir1$  (Length of stirrups along X) = 2560.00

Astir1 (stirrups area) = 78.53982  
 psh2 ((5.4d), TBDY) = Lstir2\*Astir2/(Asec\*s2) = 0.00070345  
 Lstir2 (Length of stirrups along X) = 1968.00  
 Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

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 = 257.9541

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

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

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 = 257.9541

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

yv = 0.00092863

shv = 0.00297161

ftv = 309.5449

fyv = 257.9541

suv = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

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 = 257.9541

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.06082368

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.03782183

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.06576367

and confined core properties:

b = 390.00

$d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.07329111$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.04557442$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07924369$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.24031351$   
 $Mu = MRc (4.14) = 5.8043E+008$   
 $u = su (4.1) = 5.5327066E-006$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.16198962$   
 $l_b = 300.00$   
 $l_d = 1851.971$   
 Calculation of  $l_b, \min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $l_d, \min$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 694.45$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}, A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$   
 $n = 30.00$

Calculation of  $Mu_{2+}$

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

$u = 5.2477290E-006$   
 $Mu = 3.2937E+008$

with full section properties:

$b = 950.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00093808$   
 $N = 20792.022$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01151713$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01151713$   
 $we (5.4c) = 0.04017143$   
 $ase ((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53375773$   
 $ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noconf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $a_{se2} (\geq a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noconf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53375773$

The definitions of  $A_{noconf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noconf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

-----  
 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.48363$   
 $p_{sh1} ((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$   
 $L_{stir1}$  (Length of stirrups along Y) = 2160.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $p_{sh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$   
 $L_{stir2}$  (Length of stirrups along Y) = 1568.00  
 $A_{stir2}$  (stirrups area) = 50.26548

-----  
 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.97078$   
 $p_{sh1} ((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$   
 $L_{stir1}$  (Length of stirrups along X) = 2560.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $p_{sh2} ((5.4d), \text{TBDY}) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$   
 $L_{stir2}$  (Length of stirrups along X) = 1968.00  
 $A_{stir2}$  (stirrups area) = 50.26548

-----  
 $A_{sec} = 562500.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00424426$

$c = \text{confinement factor} = 1.22443$

$y_1 = 0.00092863$

$sh_1 = 0.00297161$

$ft_1 = 309.5449$

$fy_1 = 257.9541$

$su_1 = 0.00297161$

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

$l_o/l_{ou,min} = l_b/l_d = 0.16198962$

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

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

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

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 257.9541$

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

$y_2 = 0.00092863$

$sh_2 = 0.00297161$

$ft_2 = 309.5449$

$fy_2 = 257.9541$

$su_2 = 0.00297161$

```

using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0179156
2 = Asl,com/(b*d)*(fs2/fc) = 0.02881122
v = Asl,mid/(b*d)*(fsv/fc) = 0.03115121
and confined core properties:
b = 890.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.01997081
2 = Asl,com/(b*d)*(fs2/fc) = 0.03211633
v = Asl,mid/(b*d)*(fsv/fc) = 0.03472476
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
---->
v < vs,y2 - LHS eq.(4.5) is satisfied
---->
su (4.9) = 0.19905879
Mu = MRc (4.14) = 3.2937E+008
u = su (4.1) = 5.2477290E-006
-----

Calculation of ratio lb/lb
-----
Lap Length: lb/lb = 0.16198962
lb = 300.00
lb = 1851.971
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
lb,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, 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

```



$$K_{tr} = 1.37392$$

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

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 30.00$$

Calculation of  $\mu_2$ -

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

$$\mu = 5.5327066E-006$$

$$\mu = 5.8043E+008$$

with full section properties:

$$b = 450.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00198039$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, \alpha) = 0.01151713$$

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

$$\text{From (5.4b), TB DY: } \mu = 0.01151713$$

$$\text{we (5.4c) } = 0.04017143$$

$$\alpha_{se} ((5.4d), \text{TB DY}) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.53375773$$

$$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_{se2} (>= \alpha_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$$

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$$

$$p_{sh1} ((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$$

$$L_{stir1} (\text{Length of stirrups along Y}) = 2160.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$p_{sh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$$

$$L_{stir2} (\text{Length of stirrups along Y}) = 1568.00$$

$$A_{stir2} (\text{stirrups area}) = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$$

$$p_{sh1} ((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$$

$$L_{stir1} (\text{Length of stirrups along X}) = 2560.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$psh2 ((5.4d), TBDY) = Lstir2 * Astir2 / (Asec * s2) = 0.00070345$   
 $Lstir2 (\text{Length of stirrups along } X) = 1968.00$   
 $Astir2 (\text{stirrups area}) = 50.26548$

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962

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 = 257.9541

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

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

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 = 257.9541

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

yv = 0.00092863

shv = 0.00297161

ftv = 309.5449

fyv = 257.9541

suv = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962

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 = 257.9541

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.06082368

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.03782183

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.06576367

and confined core properties:

b = 390.00

d = 677.00

```

d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.07329111
2 = Asl,com/(b*d)*(fs2/fc) = 0.04557442
v = Asl,mid/(b*d)*(fsv/fc) = 0.07924369
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.24031351
Mu = MRc (4.14) = 5.8043E+008
u = su (4.1) = 5.5327066E-006
-----

Calculation of ratio lb/ld
-----

Lap Length: lb/ld = 0.16198962
lb = 300.00
ld = 1851.971
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
ld,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, 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 = 1.37392
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) = 250.00
n = 30.00
-----

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 1.3280E+006
-----

Calculation of Shear Strength at edge 1, Vr1 = 1.3280E+006
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VCol0
VCol0 = 1.3280E+006
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 = 33.00, but fc'^0.5 <= 8.3
MPa (22.5.3.1, ACI 318-14)
M/Vd = 2.00
Mu = 1534.054
Vu = 4.6187021E-017
d = 0.8*h = 600.00
Nu = 20792.022
Ag = 337500.00
From (11.5.4.8), ACI 318-14: Vs = Vs,jacket + Vs,core = 936062.473
where:
Vs,jacket = Vs,j1 + Vs,j2 = 837764.743
Vs,j1 = 523602.964 is calculated for section web jacket, with:
d = 600.00
Av = 157079.633

```

$f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.27777778$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$   
 $V_{s,c1} = 98297.73$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.25$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 1.0304E+006$   
 $bw = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.3280E+006$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$   
 $V_{Col0} = 1.3280E+006$   
 $knl = 1$  (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:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1534.054$   
 $V_u = 4.6187021E-017$   
 $d = 0.8 * h = 600.00$   
 $N_u = 20792.022$   
 $A_g = 337500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 936062.473$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 837764.743$   
 $V_{s,j1} = 523602.964$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.27777778$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$   
 $V_{s,c1} = 98297.73$  is calculated for section web core, with:

$d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.25$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 1.0304E+006$   
 $bw = 450.00$

End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
 At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
 At Shear local axis: 2  
 (Bending local axis: 3)  
 Section Type: rcjtcs

#### Constant Properties

Knowledge Factor,  $\phi = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Jacket  
 New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 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  
 New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 450.00$   
 Max Width,  $W_{max} = 950.00$   
 Min Width,  $W_{min} = 450.00$   
 Eccentricity,  $Ecc = 250.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.22443  
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_o = 300.00$

## No FRP Wrapping

### Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = 1.3499588E-021$

EDGE -B-

Shear Force,  $V_b = -1.3499588E-021$

BOTH EDGES

Axial Force,  $F = -20792.022$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $A_{sc} = 6691.592$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{st,ten} = 1539.38$

-Compression:  $A_{st,com} = 1539.38$

-Middle:  $A_{st,mid} = 3612.832$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.22515134$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 361758.676$

with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 5.4264E+008$

$\mu_{1+} = 5.4264E+008$ , 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

$\mu_{1-} = 5.4264E+008$ , 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 5.4264E+008$

$\mu_{2+} = 5.4264E+008$ , 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

$\mu_{2-} = 5.4264E+008$ , 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:

$\mu = 4.1882964E-006$

$M_u = 5.4264E+008$

with full section properties:

$b = 450.00$

$d = 907.00$

$d' = 43.00$

$v = 0.0015437$

$N = 20792.022$

$f_c = 33.00$

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

Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01151713$

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

From (5.4b), TBDY:  $\mu_c = 0.01151713$

$\mu_{cc} \text{ (5.4c)} = 0.04017143$

$\alpha_{se} \text{ ((5.4d), TBDY)} = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.53375773$

$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and  
is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length  
equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>=ase1) = \text{Max}(((A_{conf,max2}-A_{noConf2})/A_{conf,max2})*(A_{conf,min2}/A_{conf,max2}),0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization  
of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and  
is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and  
is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length  
equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min}*F_{ywe} = \text{Min}(psh_x*F_{ywe}, psh_y*F_{ywe}) = 2.48363$

-----  
 $psh_x*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 2.48363$   
 $psh1 ((5.4d), TBDY) = L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.00301593$   
 $L_{stir1}$  (Length of stirrups along Y) = 2160.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d)) = L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00056047$   
 $L_{stir2}$  (Length of stirrups along Y) = 1568.00  
 $A_{stir2}$  (stirrups area) = 50.26548

-----  
 $psh_y*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 2.97078$   
 $psh1 ((5.4d), TBDY) = L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.00357443$   
 $L_{stir1}$  (Length of stirrups along X) = 2560.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00070345$   
 $L_{stir2}$  (Length of stirrups along X) = 1968.00  
 $A_{stir2}$  (stirrups area) = 50.26548

-----  
 $A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00424426$

$c$  = confinement factor = 1.22443

$y1 = 0.00092863$

$sh1 = 0.00297161$

$ft1 = 309.5449$

$fy1 = 257.9541$

$su1 = 0.00297161$

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

$lo/lou_{min} = lb/ld = 0.16198962$

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

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  $fs1 = (f_{s,jacket}*A_{sl,ten,jacket} + f_{s,core}*A_{sl,ten,core})/A_{sl,ten} = 257.9541$

with  $Es1 = (E_{s,jacket}*A_{sl,ten,jacket} + E_{s,core}*A_{sl,ten,core})/A_{sl,ten} = 200000.00$

$y2 = 0.00092863$

$sh2 = 0.00297161$

$ft2 = 309.5449$

$fy2 = 257.9541$

$su2 = 0.00297161$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 0.16198962$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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  $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 257.9541$   
 with  $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.00092863$   
 $sh_v = 0.00297161$   
 $ft_v = 309.5449$   
 $fy_v = 257.9541$   
 $suv = 0.00297161$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.16198962$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $fs_v = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 257.9541$   
 with  $Es_v = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.02948185$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.02948185$   
 $v = Asl_{mid} / (b * d) * (fs_v / fc) = 0.06919209$

and confined core properties:

$b = 390.00$   
 $d = 877.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.03518117$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.03518117$   
 $v = Asl_{mid} / (b * d) * (fs_v / fc) = 0.08256805$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

$su (4.9) = 0.21774786$

$Mu = MRc (4.14) = 5.4264E+008$

$u = su (4.1) = 4.1882964E-006$

-----

Calculation of ratio  $l_b/l_d$

-----

Lap Length:  $l_b/l_d = 0.16198962$

$l_b = 300.00$

$l_d = 1851.971$

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

$l_{d,min}$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 694.45$

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.37392$

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

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) = 250.00  
n = 30.00

#### Calculation of Mu1-

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

$\mu = 4.1882964E-006$

$Mu = 5.4264E+008$

with full section properties:

b = 450.00

d = 907.00

d' = 43.00

v = 0.0015437

N = 20792.022

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01151713$

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

From (5.4b), TBDY:  $\mu_c = 0.01151713$

we (5.4c) = 0.04017143

ase ((5.4d), TBDY) =  $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53375773$

ase1 =  $\text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

ase2 ( $\geq ase1$ ) =  $\text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length

equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

$A_{stir2}$  (stirrups area) = 50.26548

```

Asec = 562500.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 694.45
fce = 33.00
From ((5.A.5), TBDY), TBDY: cc = 0.00424426
c = confinement factor = 1.22443
y1 = 0.00092863
sh1 = 0.00297161
ft1 = 309.5449
fy1 = 257.9541
su1 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 257.9541
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00092863
sh2 = 0.00297161
ft2 = 309.5449
fy2 = 257.9541
su2 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.02948185
2 = Asl,com/(b*d)*(fs2/fc) = 0.02948185
v = Asl,mid/(b*d)*(fsv/fc) = 0.06919209
and confined core properties:
b = 390.00
d = 877.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426

```

$c = \text{confinement factor} = 1.22443$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03518117$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.03518117$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08256805$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su(4.9) = 0.21774786$   
 $Mu = MRc(4.14) = 5.4264E+008$   
 $u = su(4.1) = 4.1882964E-006$

Calculation of ratio  $l_b/d$

Lap Length:  $l_b/d = 0.16198962$   
 $l_b = 300.00$   
 $l_d = 1851.971$   
 Calculation of  $l_b$ ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $l_d$ ,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 694.45$   
 Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$   
 $n = 30.00$

Calculation of  $Mu_{2+}$

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 4.1882964E-006$   
 $Mu = 5.4264E+008$

with full section properties:

$b = 450.00$   
 $d = 907.00$   
 $d' = 43.00$   
 $v = 0.0015437$   
 $N = 20792.022$   
 $f_c = 33.00$   
 $\alpha(5A.5, TBDY) = 0.002$   
 Final value of  $cu^*$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01151713$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01151713$   
 $w_e(5.4c) = 0.04017143$   
 $ase((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53375773$   
 $ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 395025.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 173066.667 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.53375773$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 252164.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 111441.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 110709.333 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 2.48363$

psh\_x\*Fywe =  $psh1 * Fywe1 + ps2 * Fywe2 = 2.48363$   
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00301593$   
Lstir1 (Length of stirrups along Y) = 2160.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d)) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00056047$   
Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe =  $psh1 * Fywe1 + ps2 * Fywe2 = 2.97078$   
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00357443$   
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00070345$   
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

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

lo/lou,min =  $l_b/l_d = 0.16198962$

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

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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 257.9541$

with Es1 =  $(E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

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

lo/lou,min =  $l_b/l_{b,min} = 0.16198962$

```

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 = (fsjacket*Aslcom,jacket + fscore*Aslcom,core)/Aslcom = 257.9541
with Es2 = (Esjacket*Aslcom,jacket + Escore*Aslcom,core)/Aslcom = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962
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*Aslmid,jacket + fsmid*Aslmid,core)/Aslmid = 257.9541
with Esv = (Esjacket*Aslmid,jacket + Esmid*Aslmid,core)/Aslmid = 200000.00
1 = Aslten/(b*d)*(fs1/fc) = 0.02948185
2 = Aslcom/(b*d)*(fs2/fc) = 0.02948185
v = Aslmid/(b*d)*(fsv/fc) = 0.06919209
and confined core properties:
b = 390.00
d = 877.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Aslten/(b*d)*(fs1/fc) = 0.03518117
2 = Aslcom/(b*d)*(fs2/fc) = 0.03518117
v = Aslmid/(b*d)*(fsv/fc) = 0.08256805
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.21774786
Mu = MRc (4.14) = 5.4264E+008
u = su (4.1) = 4.1882964E-006
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.16198962
lb = 300.00
ld = 1851.971
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
ld,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, 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 = 1.37392
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) = 250.00

```

$$n = 30.00$$

Calculation of Mu2-

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

$$\mu = 4.1882964E-006$$

$$Mu = 5.4264E+008$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, co) = 0.01151713$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01151713$$

$$w_e \text{ (5.4c)} = 0.04017143$$

$$ase \text{ ((5.4d), TBDY)} = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53375773$$

$$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$$

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2160.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1568.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2560.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1968.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

```

Asec = 562500.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 694.45
fce = 33.00
From ((5A.5), TBDY), TBDY: cc = 0.00424426
c = confinement factor = 1.22443
y1 = 0.00092863
sh1 = 0.00297161
ft1 = 309.5449
fy1 = 257.9541
su1 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 257.9541
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00092863
sh2 = 0.00297161
ft2 = 309.5449
fy2 = 257.9541
su2 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.02948185
2 = Asl,com/(b*d)*(fs2/fc) = 0.02948185
v = Asl,mid/(b*d)*(fsv/fc) = 0.06919209
and confined core properties:
b = 390.00
d = 877.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443

```

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03518117$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.03518117$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08256805$$

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

---->

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

---->

$$s_u(4.9) = 0.21774786$$

$$M_u = M_{Rc}(4.14) = 5.4264E+008$$

$$u = s_u(4.1) = 4.1882964E-006$$

Calculation of ratio  $l_b/l_d$

$$\text{Lap Length: } l_b/l_d = 0.16198962$$

$$l_b = 300.00$$

$$l_d = 1851.971$$

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

$l_d$ ,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 694.45$

Mean concrete strength:  $f'_c = (f'_c_{jacket} * Area_{jacket} + f'_c_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.37392$$

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

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

$$s = \text{Max}(s_{external}, s_{internal}) = 250.00$$

$$n = 30.00$$

$$\text{Calculation of Shear Strength } V_r = \text{Min}(V_{r1}, V_{r2}) = 1.6067E+006$$

$$\text{Calculation of Shear Strength at edge 1, } V_{r1} = 1.6067E+006$$

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

$$V_{Col0} = 1.6067E+006$$

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

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

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

Mean concrete strength:  $f'_c = (f'_c_{jacket} * Area_{jacket} + f'_c_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$M_u = 1.04067$$

$$V_u = 1.3499588E-021$$

$$d = 0.8 * h = 760.00$$

$$N_u = 20792.022$$

$$A_g = 427500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{sjacket} + V_{s,core} = 1.1114E+006$$

where:

$$V_{sjacket} = V_{sj1} + V_{sj2} = 977392.20$$

$V_{sj1} = 314161.779$  is calculated for section web jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$$V_{sj1} \text{ is multiplied by } Col,j1 = 1.00$$

$$s/d = 0.27777778$$



$V_{s,j2} = 663230.422$  is calculated for section flange jacket, with:

$$d = 760.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$$s/d = 0.13157895$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$

$$s/d = 1.25$$

$V_{s,c2} = 134042.359$  is calculated for section flange core, with:

$$d = 600.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$

$$s/d = 0.41666667$$

$$V_f ((11-3)-(11.4), ACI 440) = 0.00$$

$$\text{From } (11-11), ACI 440: V_s + V_f \leq 1.3051E+006$$

$$bw = 450.00$$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.6067E+006$

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

$$V_{Col0} = 1.6067E+006$$

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

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

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

$$\text{Mean concrete strength: } f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$\mu_u = 1.04067$$

$$V_u = 1.3499588E-021$$

$$d = 0.8 * h = 760.00$$

$$N_u = 20792.022$$

$$A_g = 427500.00$$

$$\text{From } (11.5.4.8), ACI 318-14: V_s = V_{s,jacket} + V_{s,core} = 1.1114E+006$$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 977392.20$$

$V_{s,j1} = 314161.779$  is calculated for section web jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$

$$s/d = 0.27777778$$

$V_{s,j2} = 663230.422$  is calculated for section flange jacket, with:

$$d = 760.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$$s/d = 0.13157895$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.25$   
 $V_{s,c2} = 134042.359$  is calculated for section flange core, with:  
 $d = 600.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.41666667$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 1.3051E+006$   
 $bw = 450.00$

End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
 At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1  
 At local axis: 2  
 Integration Section: (a)  
 Section Type: rcjtcs

#### Constant Properties

Knowledge Factor,  $= 1.00$   
 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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 450.00$   
 Max Width,  $W_{max} = 950.00$   
 Min Width,  $W_{min} = 450.00$   
 Eccentricity,  $Ecc = 250.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_b = 300.00$   
 No FRP Wrapping

#### Stepwise Properties

Bending Moment,  $M = -210804.16$   
 Shear Force,  $V_2 = -9644.583$   
 Shear Force,  $V_3 = 108.1943$   
 Axial Force,  $F = -21706.813$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $As_t = 0.00$   
 -Compression:  $As_c = 6691.592$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $Asl_{ten} = 1539.38$

-Compression:  $Asl_{com} = 2475.575$

-Middle:  $Asl_{mid} = 2676.637$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension:  $Asl_{ten,jacket} = 1231.504$

-Compression:  $Asl_{com,jacket} = 1859.823$

-Middle:  $Asl_{mid,jacket} = 2060.885$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $Asl_{ten,core} = 307.8761$

-Compression:  $Asl_{com,core} = 615.7522$

-Middle:  $Asl_{mid,core} = 615.7522$

Mean Diameter of Tension Reinforcement,  $DbL = 16.57143$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = 1.0^*$   $u = 0.02454959$

$u = y + p = 0.02454959$

- Calculation of  $y$  -

$y = (My * Ls / 3) / E_{eff} = 0.00134118$  ((4.29), Biskinis Phd))

$My = 3.7894E+008$

$Ls = M/V$  (with  $Ls > 0.1 * L$  and  $Ls < 2 * L$ ) = 1948.386

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.8350E+014$

$factor = 0.30$

$A_g = 562500.00$

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 33.00$

$N = 21706.813$

$E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 6.1166E+014$

Calculation of Yielding Moment  $My$

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

Assuming neutral axis within flange (  $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 950.00$

web width,  $bw = 450.00$

flange thickness,  $t = 450.00$

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

$y_{ten} = 2.1201278E-006$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / d)^{2/3}) = 239.4634$

$d = 707.00$

$y = 0.20121911$

$A = 0.01009788$

$B = 0.00476485$

with  $pt = 0.00229194$

$pc = 0.00368581$

$pv = 0.00398517$

$N = 21706.813$

$b = 950.00$

$" = 0.06082037$

$y_{comp} = 1.5661056E-005$

with  $fc = 33.00$

$E_c = 26999.444$

$y = 0.19869693$

$A = 0.00988947$

$B = 0.00462988$

with  $E_s = 200000.00$

CONFIRMATION:  $y = 0.19956461 < t/d$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_d/l_{d,min} = 0.20248702$

$l_b = 300.00$

$l_d = 1481.576$

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

$l_{d,min}$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (10.3.5, ASCE 41-17)

$= 1$

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 555.56$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.37392$

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

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

$s = \max(s_{external}, s_{internal}) = 250.00$

$n = 30.00$

- Calculation of  $p$  -

From table 10-8:  $p = 0.0232084$

with:

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

shear control ratio  $V_y E / V_{col} O E = 0.29138786$

$d = d_{external} = 707.00$

$s = s_{external} = 0.00$

-  $t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.0035764$

jacket:  $s_1 = A_{v1} \cdot L_{stir1} / (s_1 \cdot A_g) = 0.00301593$

$A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir1} = 2160.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2} \cdot L_{stir2} / (s_2 \cdot A_g) = 0.00056047$

$A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir2} = 1568.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

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

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

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

For the normalisation  $f_s$  of jacket is used.

$N_{UD} = 21706.813$

$A_g = 562500.00$

$f_{cE} = (f_{c,jacket} \cdot Area_{jacket} + f_{c,core} \cdot Area_{core}) / section\_area = 33.00$

$f_{yE} = (f_{y,ext\_Long\_Reinf} \cdot Area_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} \cdot Area_{int\_Long\_Reinf}) / Area_{Tot\_Long\_Rein} = 555.56$

$f_{yE} = (f_{y,ext\_Trans\_Reinf} \cdot s_1 + f_{y,int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 555.56$

$p_l = Area_{Tot\_Long\_Rein} / (b \cdot d) = 0.00996292$

$b = 950.00$

$d = 707.00$

$f_{cE} = 33.00$

End Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1

At local axis: 2

Integration Section: (a)

## Calculation No. 11

column C1, Floor 1

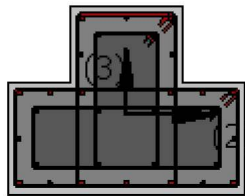
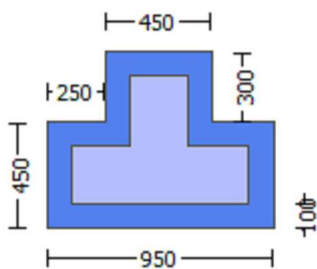
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JTC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Secondary 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

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

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

#####

Max Height, Hmax = 750.00  
 Min Height, Hmin = 450.00  
 Max Width, Wmax = 950.00  
 Min Width, Wmin = 450.00  
 Eccentricity, Ecc = 250.00  
 Jacket Thickness, tj = 100.00  
 Cover Thickness, c = 25.00  
 Element Length, L = 3000.00  
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length lo = lb = 300.00  
 No FRP Wrapping

#### Stepwise Properties

EDGE -A-  
 Bending Moment, Ma = -210804.16  
 Shear Force, Va = 108.1943  
 EDGE -B-  
 Bending Moment, Mb = -112664.662  
 Shear Force, Vb = -108.1943  
 BOTH EDGES  
 Axial Force, F = -21706.813  
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension: Aslt = 0.00  
   -Compression: Aslc = 6691.592  
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension: Asl,ten = 1539.38  
   -Compression: Asl,com = 2475.575  
   -Middle: Asl,mid = 2676.637  
 Mean Diameter of Tension Reinforcement, DbL,ten = 16.57143

New component: From table 7-7, ASCE 41\_17: Final Shear Capacity VR = 1.0\*Vn = 1.0530E+006  
 Vn ((10.3), ASCE 41-17) = knl\*VColO = 1.0530E+006  
 VCol = 1.0530E+006  
 knl = 1.00  
 displacement\_ductility\_demand = 0.01041926

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 = 25.00, but  $fc'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 M/Vd = 3.24731  
 Mu = 210804.16  
 Vu = 108.1943  
 d = 0.8\*h = 600.00  
 Nu = 21706.813  
 Ag = 337500.00  
 From (11.5.4.8), ACI 318-14: Vs = Vs,jacket + Vs,core = 842449.486  
 where:  
 Vs,jacket = Vs,j1 + Vs,j2 = 753982.237  
 Vs,j1 = 471238.898 is calculated for section web jacket, with:  
 d = 600.00  
 Av = 157079.633  
 fy = 500.00  
 s = 100.00  
 Vs,j1 is multiplied by Col,j1 = 1.00  
 s/d = 0.16666667

$V_{s,j2} = 282743.339$  is calculated for section flange jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 500.00$$

$$s = 100.00$$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$$s/d = 0.27777778$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 88467.249$$

$V_{s,c1} = 88467.249$  is calculated for section web core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 500.00$$

$$s = 250.00$$

$V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$

$$s/d = 0.56818182$$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 500.00$$

$$s = 250.00$$

$V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$

$$s/d = 1.25$$

$$V_f ((11-3)-(11.4), ACI 440) = 0.00$$

$$\text{From } (11-11), ACI 440: V_s + V_f \leq 896810.169$$

$$bw = 450.00$$

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  $\theta = 1.3974154E-005$

$$y = (M_y * L_s / 3) / E_{eff} = 0.00134118 ((4.29), Biskinis Phd))$$

$$M_y = 3.7894E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 1948.386$$

From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} * E_c * I_g = 1.8350E+014$

$$\text{factor} = 0.30$$

$$A_g = 562500.00$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$$

$$N = 21706.813$$

$$E_c * I_g = E_c * I_{g,jacket} + E_c * I_{g,core} = 6.1166E+014$$

Calculation of Yielding Moment  $M_y$

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

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

$$\text{flange width, } b = 950.00$$

$$\text{web width, } bw = 450.00$$

$$\text{flange thickness, } t = 450.00$$

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

$$y_{ten} = 2.1201278E-006$$

$$\text{with } ((10.1), ASCE 41-17) f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 239.4634$$

$$d = 707.00$$

$$y = 0.20121911$$

$$A = 0.01009788$$

$$B = 0.00476485$$

$$\text{with } pt = 0.00229194$$

$$pc = 0.00368581$$

$$pv = 0.00398517$$

$$N = 21706.813$$

$$b = 950.00$$

" = 0.06082037  
y\_comp = 1.5661056E-005  
with fc = 33.00  
Ec = 26999.444  
y = 0.19869693  
A = 0.00988947  
B = 0.00462988  
with Es = 200000.00  
CONFIRMATION: y = 0.19956461 < t/d

-----

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

-----

Lap Length: l<sub>d</sub>/l<sub>d,min</sub> = 0.20248702  
lb = 300.00  
l<sub>d</sub> = 1481.576  
Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
l<sub>d,min</sub> from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (10.3.5, ASCE 41-17)  
= 1  
db = 16.66667  
Mean strength value of all re-bars: f<sub>y</sub> = 555.56  
Mean concrete strength: f<sub>c'</sub> = (f<sub>c'</sub><sub>jacket</sub>\*Area<sub>jacket</sub> + f<sub>c'</sub><sub>core</sub>\*Area<sub>core</sub>)/Area<sub>section</sub> = 33.00, but f<sub>c'</sub><sup>0.5</sup> ≤ 8.3  
MPa (22.5.3.1, ACI 318-14)  
t = 1.00  
s = 0.80  
e = 1.00  
cb = 25.00  
K<sub>tr</sub> = 1.37392  
A<sub>tr</sub> = Min(A<sub>tr,x</sub>, A<sub>tr,y</sub>) = 257.6106  
where A<sub>tr,x</sub>, A<sub>tr,y</sub> are the sum of the area of all stirrup legs along X and Y local axis  
s = Max(s<sub>external</sub>, s<sub>internal</sub>) = 250.00  
n = 30.00

-----

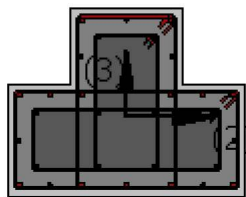
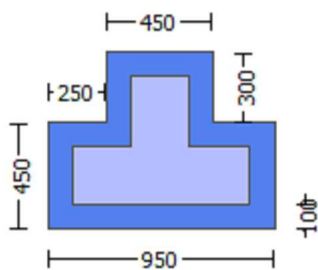
End Of Calculation of Shear Capacity for element: column JTC1 of floor 1  
At local axis: 3  
Integration Section: (a)

-----

## Calculation No. 12

column C1, Floor 1  
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)  
Analysis: Uniform +X  
Check: Chord rotation capacity (  $\phi$  )  
Edge: Start  
Local Axis: (3)





Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $Ecc = 250.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.22443

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

No FRP Wrapping

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 4.6187021E-017$

EDGE -B-

Shear Force,  $V_b = -4.6187021E-017$

BOTH EDGES

Axial Force,  $F = -20792.022$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 6691.592$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 1539.38$

-Compression:  $As_{c,com} = 2475.575$

-Middle:  $As_{mid} = 2676.637$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.29138786$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 386950.491$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 5.8043E+008$

$Mu_{1+} = 3.2937E+008$ , 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

$Mu_{1-} = 5.8043E+008$ , 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 5.8043E+008$

$Mu_{2+} = 3.2937E+008$ , 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

$Mu_{2-} = 5.8043E+008$ , 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:

$\phi_u = 5.2477290E-006$

$M_u = 3.2937E+008$

with full section properties:

$b = 950.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093808$

$N = 20792.022$

$f_c = 33.00$

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

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01151713$

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

From (5.4b), TBDY:  $\phi_u = 0.01151713$

we (5.4c) = 0.04017143

$\phi_{se}$  ((5.4d), TBDY) =  $(\phi_{se1} * A_{ext} + \phi_{se2} * A_{int}) / A_{sec} = 0.53375773$

$\phi_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\phi_{se2} (>= \phi_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$   
 $psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$   
 $L_{stir1}$  (Length of stirrups along Y) = 2160.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$   
 $L_{stir2}$  (Length of stirrups along Y) = 1568.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$   
 $psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$   
 $L_{stir1}$  (Length of stirrups along X) = 2560.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$   
 $L_{stir2}$  (Length of stirrups along X) = 1968.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00424426$

$c = \text{confinement factor} = 1.22443$

$y1 = 0.00092863$

$sh1 = 0.00297161$

$ft1 = 309.5449$

$fy1 = 257.9541$

$su1 = 0.00297161$

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

$lo/lou_{min} = lb/ld = 0.16198962$

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

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  $fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 257.9541$

with  $Es1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.00092863$

$sh2 = 0.00297161$

$ft2 = 309.5449$

$fy2 = 257.9541$

$su2 = 0.00297161$

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

$lo/lou_{min} = lb/lb_{min} = 0.16198962$

$su2 = 0.4 * esu2_{nominal} ((5.5), TBDY) = 0.032$

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  $fs2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 257.9541$

with  $Es2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$

$yv = 0.00092863$

```

shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
    using (30) in Biskinis/Fardis (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 = 0.16198962
    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 = 257.9541
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0179156
2 = Asl,com/(b*d)*(fs2/fc) = 0.02881122
v = Asl,mid/(b*d)*(fsv/fc) = 0.03115121
and confined core properties:
b = 890.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
    c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.01997081
2 = Asl,com/(b*d)*(fs2/fc) = 0.03211633
v = Asl,mid/(b*d)*(fsv/fc) = 0.03472476
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.19905879
Mu = MRc (4.14) = 3.2937E+008
u = su (4.1) = 5.2477290E-006
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.16198962
lb = 300.00
ld = 1851.971
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
ld,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)
    = 1
db = 16.66667
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, 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 = 1.37392
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) = 250.00
n = 30.00
-----
-----
-----
Calculation of Mu1-
-----
-----

```

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

$$u = 5.5327066E-006$$

$$\mu = 5.8043E+008$$

with full section properties:

$$b = 450.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00198039$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01151713$$

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

$$\text{From (5.4b), TB DY: } \phi_u = 0.01151713$$

$$\phi_{ue} (5.4c) = 0.04017143$$

$$\phi_{ase} ((5.4d), \text{TB DY}) = (\phi_{ase1} * A_{ext} + \phi_{ase2} * A_{int}) / A_{sec} = 0.53375773$$

$$\phi_{ase1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i d_i / 6$  as defined at (A.2).

$$\phi_{ase2} (> \phi_{ase1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i d_i / 6$  as defined at (A.2).

$$\phi_{psh,min} * F_{ywe} = \text{Min}(\phi_{psh,x} * F_{ywe}, \phi_{psh,y} * F_{ywe}) = 2.48363$$

$$\phi_{psh,x} * F_{ywe} = \phi_{psh1} * F_{ywe1} + \phi_{ps2} * F_{ywe2} = 2.48363$$

$$\phi_{psh1} ((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$$

$$L_{stir1} (\text{Length of stirrups along Y}) = 2160.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$\phi_{psh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$$

$$L_{stir2} (\text{Length of stirrups along Y}) = 1568.00$$

$$A_{stir2} (\text{stirrups area}) = 50.26548$$

$$\phi_{psh,y} * F_{ywe} = \phi_{psh1} * F_{ywe1} + \phi_{ps2} * F_{ywe2} = 2.97078$$

$$\phi_{psh1} ((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$$

$$L_{stir1} (\text{Length of stirrups along X}) = 2560.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$\phi_{psh2} ((5.4d), \text{TB DY}) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$$

$$L_{stir2} (\text{Length of stirrups along X}) = 1968.00$$

$$A_{stir2} (\text{stirrups area}) = 50.26548$$

$$A_{sec} = 562500.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \phi_c = 0.00424426$$

$$\phi_c = \text{confinement factor} = 1.22443$$

```

y1 = 0.00092863
sh1 = 0.00297161
ft1 = 309.5449
fy1 = 257.9541
su1 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962
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 = 257.9541
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00092863
sh2 = 0.00297161
ft2 = 309.5449
fy2 = 257.9541
su2 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.06082368
2 = Asl,com/(b*d)*(fs2/fc) = 0.03782183
v = Asl,mid/(b*d)*(fsv/fc) = 0.06576367
and confined core properties:
b = 390.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.07329111
2 = Asl,com/(b*d)*(fs2/fc) = 0.04557442
v = Asl,mid/(b*d)*(fsv/fc) = 0.07924369
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
---->
v < vs,y2 - LHS eq.(4.5) is satisfied
---->

```

$s_u(4.9) = 0.24031351$   
 $\mu = M_{Rc}(4.14) = 5.8043E+008$   
 $u = s_u(4.1) = 5.5327066E-006$

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

Lap Length:  $l_b/l_d = 0.16198962$

$l_b = 300.00$

$l_d = 1851.971$

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

$l_d$ ,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 694.45$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.37392$

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

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

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 30.00$

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

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

$u = 5.2477290E-006$

$\mu = 3.2937E+008$

with full section properties:

$b = 950.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093808$

$N = 20792.022$

$f_c = 33.00$

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

Final value of  $\phi$ :  $\phi^* = \text{shear\_factor} \cdot \text{Max}(\phi, \phi_c) = 0.01151713$

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

From (5.4b), TBDY:  $\phi = 0.01151713$

we (5.4c)  $\phi = 0.04017143$

$\phi_{ase}((5.4d), \text{TBDY}) = (\phi_{ase1} \cdot A_{ext} + \phi_{ase2} \cdot A_{int}) / A_{sec} = 0.53375773$

$\phi_{ase1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length

equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\phi_{ase2} (\geq \phi_{ase1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) \cdot (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 252164.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 111441.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 110709.333 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 2.48363

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 2.48363  
psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00301593  
Lstir1 (Length of stirrups along Y) = 2160.00  
Astir1 (stirrups area) = 78.53982  
psh2 (5.4d) = Lstir2\*Astir2/(Asec\*s2) = 0.00056047  
Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 2.97078  
psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00357443  
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) = Lstir2\*Astir2/(Asec\*s2) = 0.00070345  
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

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 = 257.9541

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

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

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 = 257.9541

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

yv = 0.00092863

shv = 0.00297161



```

ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
    using (30) in Biskinis/Fardis (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 = 0.16198962
    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 = 257.9541
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.0179156
    2 = Asl,com/(b*d)*(fs2/fc) = 0.02881122
    v = Asl,mid/(b*d)*(fsv/fc) = 0.03115121
and confined core properties:
b = 890.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
    c = confinement factor = 1.22443
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.01997081
    2 = Asl,com/(b*d)*(fs2/fc) = 0.03211633
    v = Asl,mid/(b*d)*(fsv/fc) = 0.03472476
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.19905879
Mu = MRc (4.14) = 3.2937E+008
u = su (4.1) = 5.2477290E-006
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.16198962
lb = 300.00
ld = 1851.971
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
ld,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, 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 = 1.37392
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) = 250.00
n = 30.00
-----
-----
Calculation of Mu2-
-----
-----
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

```

u = 5.5327066E-006  
Mu = 5.8043E+008

with full section properties:

b = 450.00  
d = 707.00  
d' = 43.00  
v = 0.00198039  
N = 20792.022  
fc = 33.00  
co (5A.5, TBDY) = 0.002

Final value of cu:  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01151713$

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

From (5.4b), TBDY:  $cu = 0.01151713$

we (5.4c) = 0.04017143

ase ((5.4d), TBDY) =  $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53375773$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i d_i / 6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i d_i / 6$  as defined at (A.2).

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$

$psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 ((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$

$psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 ((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00424426$

c = confinement factor = 1.22443

$y1 = 0.00092863$

```

sh1 = 0.00297161
ft1 = 309.5449
fy1 = 257.9541
su1 = 0.00297161
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 0.16198962
    su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu1_nominal = 0.08,
    For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
    characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
    with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 257.9541
    with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00092863
sh2 = 0.00297161
ft2 = 309.5449
fy2 = 257.9541
su2 = 0.00297161
    using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
    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 = 257.9541
    with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 0.16198962
    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 = 257.9541
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.06082368
2 = Asl,com/(b*d)*(fs2/fc) = 0.03782183
v = Asl,mid/(b*d)*(fsv/fc) = 0.06576367
and confined core properties:
b = 390.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.07329111
2 = Asl,com/(b*d)*(fs2/fc) = 0.04557442
v = Asl,mid/(b*d)*(fsv/fc) = 0.07924369
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.24031351

```

$$\begin{aligned} \mu &= M_{Rc} (4.14) = 5.8043E+008 \\ u &= s_u (4.1) = 5.5327066E-006 \end{aligned}$$

Calculation of ratio  $l_b/l_d$

$$\text{Lap Length: } l_b/l_d = 0.16198962$$

$$l_b = 300.00$$

$$l_d = 1851.971$$

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

$l_d$ ,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

$$= 1$$

$$d_b = 16.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 694.45$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.37392$$

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

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 30.00$$

$$\text{Calculation of Shear Strength } V_r = \text{Min}(V_{r1}, V_{r2}) = 1.3280E+006$$

$$\text{Calculation of Shear Strength at edge 1, } V_{r1} = 1.3280E+006$$

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

$$V_{Co10} = 1.3280E+006$$

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

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).

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

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/V_d = 2.00$$

$$\mu_u = 1534.054$$

$$V_u = 4.6187021E-017$$

$$d = 0.8 \cdot h = 600.00$$

$$N_u = 20792.022$$

$$A_g = 337500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{sj1} + V_{sj2} = 936062.473$$

where:

$$V_{sj1} = V_{sj1} + V_{sj2} = 837764.743$$

$V_{sj1} = 523602.964$  is calculated for section web jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$$V_{sj1} \text{ is multiplied by } \text{Col}_{j1} = 1.00$$

$$s/d = 0.16666667$$

$V_{sj2} = 314161.779$  is calculated for section flange jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$$V_{sj2} \text{ is multiplied by } \text{Col}_{j2} = 1.00$$

$$s/d = 0.27777778$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.25$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 1.0304E+006$   
 $bw = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.3280E+006$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$   
 $V_{Col0} = 1.3280E+006$   
 $knl = 1$  (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:  $f'_c = (f'_c\_jacket * Area\_jacket + f'_c\_core * Area\_core) / Area\_section = 33.00$ , but  $f'_c^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1534.054$   
 $V_u = 4.6187021E-017$   
 $d = 0.8 * h = 600.00$   
 $N_u = 20792.022$   
 $A_g = 337500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 936062.473$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 837764.743$   
 $V_{s,j1} = 523602.964$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.27777778$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$   
 $V_{s,c1} = 98297.73$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.25$

Vf ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440:  $V_s + V_f \leq 1.0304E+006$   
bw = 450.00

End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjctcs

#### Constant Properties

Knowledge Factor,  $\gamma = 1.00$   
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Jacket  
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
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  
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
#####  
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 450.00$   
Max Width,  $W_{max} = 950.00$   
Min Width,  $W_{min} = 450.00$   
Eccentricity,  $Ecc = 250.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.22443  
Element Length,  $L = 3000.00$   
Secondary Member  
Smooth Bars  
Ductile Steel  
With Detailing for Earthquake Resistance (including stirrups closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = 300.00$   
No FRP Wrapping

#### Stepwise Properties

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = 1.3499588E-021$   
EDGE -B-  
Shear Force,  $V_b = -1.3499588E-021$   
BOTH EDGES  
Axial Force,  $F = -20792.022$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $Asl_t = 0.00$   
 -Compression:  $Asl_c = 6691.592$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $Asl_{ten} = 1539.38$   
 -Compression:  $Asl_{com} = 1539.38$   
 -Middle:  $Asl_{mid} = 3612.832$

Calculation of Shear Capacity ratio ,  $Ve/V_r = 0.22515134$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $Ve = (M_{pr1} + M_{pr2})/l_n = 361758.676$   
 with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 5.4264E+008$

$\mu_{1+} = 5.4264E+008$ , 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

$\mu_{1-} = 5.4264E+008$ , 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 5.4264E+008$

$\mu_{2+} = 5.4264E+008$ , 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

$\mu_{2-} = 5.4264E+008$ , 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:

$\mu = 4.1882964E-006$

$\mu_u = 5.4264E+008$

with full section properties:

$b = 450.00$

$d = 907.00$

$d' = 43.00$

$v = 0.0015437$

$N = 20792.022$

$f_c = 33.00$

$\alpha_0$  (5A.5, TBDY) = 0.002

Final value of  $\alpha_u$ :  $\alpha_u = \text{shear\_factor} * \text{Max}(\alpha_c, \alpha_0) = 0.01151713$

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

From (5.4b), TBDY:  $\alpha_c = 0.01151713$

$\alpha_{se}$  (5.4c) = 0.04017143

$\alpha_{se}((5.4d), \text{TBDY}) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.53375773$

$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\alpha_{se2} (>= \alpha_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 111441.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 110709.333 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 2.48363$

---

$psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.48363$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1*Astir1/(Asec*s1) = 0.00301593$   
 $Lstir1 \text{ (Length of stirrups along Y)} = 2160.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ (5.4d)} = Lstir2*Astir2/(Asec*s2) = 0.00056047$   
 $Lstir2 \text{ (Length of stirrups along Y)} = 1568.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

---

$psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.97078$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1*Astir1/(Asec*s1) = 0.00357443$   
 $Lstir1 \text{ (Length of stirrups along X)} = 2560.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ ((5.4d), TBDY)} = Lstir2*Astir2/(Asec*s2) = 0.00070345$   
 $Lstir2 \text{ (Length of stirrups along X)} = 1968.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

---

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962

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 = 257.9541

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

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

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 = 257.9541

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

yv = 0.00092863

shv = 0.00297161

ftv = 309.5449

fyv = 257.9541

suv = 0.00297161



using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.16198962$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $y_v$ ,  $shv$ ,  $ftv$ ,  $fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 257.9541$   
 with  $Esv = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.02948185$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.02948185$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.06919209$

and confined core properties:

$b = 390.00$   
 $d = 877.00$   
 $d' = 13.00$   
 $fcc$  (5A.2, TBDY) = 40.40604  
 $cc$  (5A.5, TBDY) = 0.00424426  
 $c$  = confinement factor = 1.22443  
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.03518117$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.03518117$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.08256805$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su$  (4.9) = 0.21774786  
 $Mu = MRc$  (4.14) = 5.4264E+008  
 $u = su$  (4.1) = 4.1882964E-006

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.16198962$

$l_b = 300.00$

$l_d = 1851.971$

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

$l_d,min$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 694.45$

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.37392$

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

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

$s = Max(s_{external}, s_{internal}) = 250.00$

$n = 30.00$

Calculation of  $Mu_1$ -

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

$u = 4.1882964E-006$

$Mu = 5.4264E+008$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_o) = 0.01151713$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01151713$$

$$w_e(5.4c) = 0.04017143$$

$$a_{se}((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53375773$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i d_i / 6$  as defined at (A.2).

$$a_{se2}(>=a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i d_i / 6$  as defined at (A.2).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$$

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$$

$$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$$

$$L_{stir1}(\text{Length of stirrups along Y}) = 2160.00$$

$$A_{stir1}(\text{stirrups area}) = 78.53982$$

$$p_{sh2}((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$$

$$L_{stir2}(\text{Length of stirrups along Y}) = 1568.00$$

$$A_{stir2}(\text{stirrups area}) = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$$

$$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$$

$$L_{stir1}(\text{Length of stirrups along X}) = 2560.00$$

$$A_{stir1}(\text{stirrups area}) = 78.53982$$

$$p_{sh2}((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$$

$$L_{stir2}(\text{Length of stirrups along X}) = 1968.00$$

$$A_{stir2}(\text{stirrups area}) = 50.26548$$

$$A_{sec} = 562500.00$$

$$s_1 = 100.00$$

$$s_2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00424426$$

$$c = \text{confinement factor} = 1.22443$$

$$y_1 = 0.00092863$$

$$sh_1 = 0.00297161$$

$$ft_1 = 309.5449$$

$$fy_1 = 257.9541$$

```

su1 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 257.9541
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00092863
sh2 = 0.00297161
ft2 = 309.5449
fy2 = 257.9541
su2 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.02948185
2 = Asl,com/(b*d)*(fs2/fc) = 0.02948185
v = Asl,mid/(b*d)*(fsv/fc) = 0.06919209
and confined core properties:
b = 390.00
d = 877.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.03518117
2 = Asl,com/(b*d)*(fs2/fc) = 0.03518117
v = Asl,mid/(b*d)*(fsv/fc) = 0.08256805
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.21774786
Mu = MRc (4.14) = 5.4264E+008
u = su (4.1) = 4.1882964E-006

```

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

Lap Length:  $l_b/l_d = 0.16198962$

$l_b = 300.00$

$l_d = 1851.971$

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

$l_d$ ,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 694.45$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.37392$

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

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

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$

$n = 30.00$

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

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

$\mu = 4.1882964\text{E-}006$

$\mu_u = 5.4264\text{E+}008$

with full section properties:

$b = 450.00$

$d = 907.00$

$d' = 43.00$

$v = 0.0015437$

$N = 20792.022$

$f_c = 33.00$

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

Final value of  $\phi_c$ :  $\phi_c = \text{shear\_factor} \cdot \text{Max}(\phi_c, \phi_c) = 0.01151713$

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

From (5.4b), TBDY:  $\phi_c = 0.01151713$

$\phi_{we}$  (5.4c) = 0.04017143

$\phi_{ase}$  ((5.4d), TBDY) =  $(\phi_{ase1} \cdot A_{ext} + \phi_{ase2} \cdot A_{int}) / A_{sec} = 0.53375773$

$\phi_{ase1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length

equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b^2/6$  as defined at (A.2).

$\phi_{ase2} (\geq \phi_{ase1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) \cdot (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 110709.333 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 2.48363$

---

$psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.48363$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1*Astir1/(Asec*s1) = 0.00301593$   
 $Lstir1 \text{ (Length of stirrups along Y)} = 2160.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ (5.4d)} = Lstir2*Astir2/(Asec*s2) = 0.00056047$   
 $Lstir2 \text{ (Length of stirrups along Y)} = 1568.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

---

$psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.97078$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1*Astir1/(Asec*s1) = 0.00357443$   
 $Lstir1 \text{ (Length of stirrups along X)} = 2560.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ ((5.4d), TBDY)} = Lstir2*Astir2/(Asec*s2) = 0.00070345$   
 $Lstir2 \text{ (Length of stirrups along X)} = 1968.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

---

$Asec = 562500.00$   
 $s1 = 100.00$   
 $s2 = 250.00$   
 $fywe1 = 694.45$   
 $fywe2 = 694.45$   
 $fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$

$y1 = 0.00092863$   
 $sh1 = 0.00297161$   
 $ft1 = 309.5449$   
 $fy1 = 257.9541$   
 $su1 = 0.00297161$

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

$lo/lou,min = lb/ld = 0.16198962$

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

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  $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 257.9541$

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

$y2 = 0.00092863$   
 $sh2 = 0.00297161$   
 $ft2 = 309.5449$   
 $fy2 = 257.9541$   
 $su2 = 0.00297161$

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

$lo/lou,min = lb/lb,min = 0.16198962$

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

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  $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 257.9541$

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

$yv = 0.00092863$   
 $shv = 0.00297161$   
 $ftv = 309.5449$   
 $fyv = 257.9541$   
 $suv = 0.00297161$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.16198962$   
 $s_{uv} = 0.4 * e_{suv\_nominal} ((5.5), TBDY) = 0.032$   
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  $y_v$ ,  $sh_v$ ,  $f_{tv}$ ,  $f_{yv}$ , it is considered  
characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1$ ,  $f_{t1}$ ,  $f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $f_{sv} = (f_{s,jacket} * A_{sl,mid,jacket} + f_{s,mid} * A_{sl,mid,core}) / A_{sl,mid} = 257.9541$   
with  $E_{sv} = (E_{s,jacket} * A_{sl,mid,jacket} + E_{s,mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b * d) * (f_{s1} / f_c) = 0.02948185$   
 $2 = A_{sl,com} / (b * d) * (f_{s2} / f_c) = 0.02948185$   
 $v = A_{sl,mid} / (b * d) * (f_{sv} / f_c) = 0.06919209$   
and confined core properties:  
 $b = 390.00$   
 $d = 877.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 40.40604$   
 $c_c (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = A_{sl,ten} / (b * d) * (f_{s1} / f_c) = 0.03518117$   
 $2 = A_{sl,com} / (b * d) * (f_{s2} / f_c) = 0.03518117$   
 $v = A_{sl,mid} / (b * d) * (f_{sv} / f_c) = 0.08256805$   
Case/Assumption: Unconfined full section - Steel rupture  
'satisfies Eq. (4.3)  
--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
--->  
 $su (4.9) = 0.21774786$   
 $M_u = M_{Rc} (4.14) = 5.4264E+008$   
 $u = su (4.1) = 4.1882964E-006$   
-----  
Calculation of ratio  $l_b/l_d$   
-----  
Lap Length:  $l_b/l_d = 0.16198962$   
 $l_b = 300.00$   
 $l_d = 1851.971$   
Calculation of  $l_b,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $l_d,min$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
 $= 1$   
 $db = 16.66667$   
Mean strength value of all re-bars:  $f_y = 694.45$   
Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$   
where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$   
 $n = 30.00$   
-----  
Calculation of  $M_{u2}$ -  
-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 4.1882964E-006$   
 $M_u = 5.4264E+008$   
-----  
with full section properties:

$b = 450.00$   
 $d = 907.00$   
 $d' = 43.00$   
 $v = 0.0015437$   
 $N = 20792.022$   
 $fc = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = shear\_factor * Max(cu, cc) = 0.01151713$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01151713$   
 $we (5.4c) = 0.04017143$   
 $ase ((5.4d), TBDY) = (ase1 * Aext + ase2 * Aint) / Asec = 0.53375773$   
 $ase1 = Max(((Aconf,max1 - AnoConf1) / Aconf,max1) * (Aconf,min1 / Aconf,max1), 0) = 0.53375773$   
 The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $Aconf,max1 = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $Aconf,min1 = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.  
 $AnoConf1 = 173066.667$  is the unconfined external core area which is equal to  $bi^2/6$  as defined at (A.2).  
 $ase2 (>= ase1) = Max(((Aconf,max2 - AnoConf2) / Aconf,max2) * (Aconf,min2 / Aconf,max2), 0) = 0.53375773$   
 The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $Aconf,max2 = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
 $Aconf,min2 = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.  
 $AnoConf2 = 110709.333$  is the unconfined internal core area which is equal to  $bi^2/6$  as defined at (A.2).  
 $psh,min * Fywe = Min(psh,x * Fywe, psh,y * Fywe) = 2.48363$

---

$psh\_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.48363$   
 $psh1 ((5.4d), TBDY) = Lstir1 * Astir1 / (Asec * s1) = 0.00301593$   
 $Lstir1$  (Length of stirrups along Y) = 2160.00  
 $Astir1$  (stirrups area) = 78.53982  
 $psh2 (5.4d) = Lstir2 * Astir2 / (Asec * s2) = 0.00056047$   
 $Lstir2$  (Length of stirrups along Y) = 1568.00  
 $Astir2$  (stirrups area) = 50.26548

---

$psh\_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.97078$   
 $psh1 ((5.4d), TBDY) = Lstir1 * Astir1 / (Asec * s1) = 0.00357443$   
 $Lstir1$  (Length of stirrups along X) = 2560.00  
 $Astir1$  (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = Lstir2 * Astir2 / (Asec * s2) = 0.00070345$   
 $Lstir2$  (Length of stirrups along X) = 1968.00  
 $Astir2$  (stirrups area) = 50.26548

---

$Asec = 562500.00$   
 $s1 = 100.00$   
 $s2 = 250.00$   
 $fywe1 = 694.45$   
 $fywe2 = 694.45$   
 $fce = 33.00$   
 From ((5.A5), TBDY), TBDY:  $cc = 0.00424426$   
 $c =$  confinement factor = 1.22443  
 $y1 = 0.00092863$   
 $sh1 = 0.00297161$   
 $ft1 = 309.5449$   
 $fy1 = 257.9541$   
 $su1 = 0.00297161$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/ld = 0.16198962$   
 $su1 = 0.4*esu1\_nominal ((5.5), TBDY) = 0.032$   
 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  $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 257.9541$   
 with  $Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00$   
 $y2 = 0.00092863$   
 $sh2 = 0.00297161$   
 $ft2 = 309.5449$   
 $fy2 = 257.9541$   
 $su2 = 0.00297161$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/lb,min = 0.16198962$   
 $su2 = 0.4*esu2\_nominal ((5.5), TBDY) = 0.032$   
 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  $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 257.9541$   
 with  $Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$   
 $yv = 0.00092863$   
 $shv = 0.00297161$   
 $ftv = 309.5449$   
 $fyv = 257.9541$   
 $suv = 0.00297161$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/ld = 0.16198962$   
 $suv = 0.4*esuv\_nominal ((5.5), TBDY) = 0.032$   
 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  $fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 257.9541$   
 with  $Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.02948185$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.02948185$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.06919209$   
 and confined core properties:  
 $b = 390.00$   
 $d = 877.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.03518117$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.03518117$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.08256805$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < vs,y2$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.21774786$   
 $Mu = MRc (4.14) = 5.4264E+008$   
 $u = su (4.1) = 4.1882964E-006$



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

Lap Length:  $l_b/l_d = 0.16198962$

$l_b = 300.00$

$l_d = 1851.971$

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

$l_d$ ,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 694.45$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.37392$

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

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

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$

$n = 30.00$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.6067\text{E}+006$

Calculation of Shear Strength at edge 1,  $V_{r1} = 1.6067\text{E}+006$

$V_{r1} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} \cdot V_{\text{Col}0}$

$V_{\text{Col}0} = 1.6067\text{E}+006$

$k_{nl} = 1$  (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:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.04067$

$V_u = 1.3499588\text{E}+021$

$d = 0.8 \cdot h = 760.00$

$N_u = 20792.022$

$A_g = 427500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 1.1114\text{E}+006$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 977392.20$

$V_{s,j1} = 314161.779$  is calculated for section web jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 1.00$

$s/d = 0.27777778$

$V_{s,j2} = 663230.422$  is calculated for section flange jacket, with:

$d = 760.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 1.00$

$s/d = 0.13157895$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 134042.359$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.25$   
 $V_{s,c2} = 134042.359$  is calculated for section flange core, with:  
 $d = 600.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.41666667$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 1.3051E+006$   
 $bw = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.6067E+006$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$   
 $V_{Col0} = 1.6067E+006$   
 $knl = 1$  (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:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.04067$   
 $V_u = 1.3499588E-021$   
 $d = 0.8 * h = 760.00$   
 $N_u = 20792.022$   
 $A_g = 427500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 1.1114E+006$   
 where:  
 $V_{sjacket} = V_{sj1} + V_{sj2} = 977392.20$   
 $V_{sj1} = 314161.779$  is calculated for section web jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{sj1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.27777778$   
 $V_{sj2} = 663230.422$  is calculated for section flange jacket, with:  
 $d = 760.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{sj2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.13157895$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.25$   
 $V_{s,c2} = 134042.359$  is calculated for section flange core, with:  
 $d = 600.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.41666667$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 1.3051E+006$   
 $bw = 450.00$

End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1  
At local axis: 3  
Integration Section: (a)  
Section Type: rcjtcs

#### Constant Properties

Knowledge Factor,  $\gamma = 1.00$   
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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 450.00$   
Max Width,  $W_{max} = 950.00$   
Min Width,  $W_{min} = 450.00$   
Eccentricity,  $E_{cc} = 250.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Secondary Member  
Smooth Bars  
Ductile Steel  
With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_b = 300.00$   
No FRP Wrapping

#### Stepwise Properties

Bending Moment,  $M = -2.9148E+007$   
Shear Force,  $V_2 = -9644.583$   
Shear Force,  $V_3 = 108.1943$   
Axial Force,  $F = -21706.813$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten} = 1539.38$   
-Compression:  $A_{sc,com} = 1539.38$   
-Middle:  $A_{sc,mid} = 3612.832$   
Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten,jacket} = 1231.504$   
-Compression:  $A_{sc,com,jacket} = 1231.504$   
-Middle:  $A_{sc,mid,jacket} = 2689.203$   
Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten,core} = 307.8761$   
-Compression:  $A_{sc,com,core} = 307.8761$   
-Middle:  $A_{sc,mid,core} = 923.6282$   
Mean Diameter of Tension Reinforcement,  $Db_L = 16.57143$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = 1.0^* u = 0.02929806$   
 $u = y + p = 0.02929806$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00188076$  ((4.29), Biskinis Phd))  
 $M_y = 5.2064E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3022.232  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.7887E+014$   
 $factor = 0.30$   
 $A_g = 562500.00$   
Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 33.00$   
 $N = 21706.813$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 9.2958E+014$

Calculation of Yielding Moment  $M_y$

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

$y = \min(y_{ten}, y_{com})$   
 $y_{ten} = 1.7803962E-006$   
with ((10.1), ASCE 41-17)  $f_y = \min(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 239.4634$   
 $d = 907.00$   
 $y = 0.25854434$   
 $A = 0.01661703$   
 $B = 0.0088082$   
with  $p_t = 0.0037716$   
 $p_c = 0.0037716$   
 $p_v = 0.00885172$   
 $N = 21706.813$   
 $b = 450.00$   
 $" = 0.04740904$   
 $y_{comp} = 9.4777698E-006$   
with  $fc = 33.00$   
 $E_c = 26999.444$   
 $y = 0.25592822$   
 $A = 0.01627407$   
 $B = 0.0085861$   
with  $E_s = 200000.00$

Calculation of ratio  $I_b / I_d$

Lap Length:  $I_d / I_{d,min} = 0.20248702$   
 $I_b = 300.00$   
 $I_d = 1481.576$   
Calculation of  $I$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $I_{d,min}$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (10.3.5, ASCE 41-17)  
 $= 1$   
 $db = 16.66667$   
Mean strength value of all re-bars:  $f_y = 555.56$   
Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$   
 $n = 30.00$

- Calculation of  $p$  -

From table 10-8:  $p = 0.0274173$

with:

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

shear control ratio  $V_y E / V_{Col} O E = 0.22515134$

$d = d_{\text{external}} = 907.00$

$s = s_{\text{external}} = 0.00$

-  $t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00427788$

jacket:  $s_1 = A_{v1} \cdot L_{stir1} / (s_1 \cdot A_g) = 0.00357443$

$A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir1} = 2560.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2} \cdot L_{stir2} / (s_2 \cdot A_g) = 0.00070345$

$A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir2} = 1968.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

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

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

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

For the normalisation  $f_s$  of jacket is used.

$NUD = 21706.813$

$A_g = 562500.00$

$f_{cE} = (f_{c\_jacket} \cdot \text{Area\_jacket} + f_{c\_core} \cdot \text{Area\_core}) / \text{section\_area} = 33.00$

$f_{yIE} = (f_{y\_ext\_Long\_Reinf} \cdot \text{Area\_ext\_Long\_Reinf} + f_{y\_int\_Long\_Reinf} \cdot \text{Area\_int\_Long\_Reinf}) / \text{Area\_Tot\_Long\_Rein} = 555.56$

$f_{yIE} = (f_{y\_ext\_Trans\_Reinf} \cdot s_1 + f_{y\_int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 555.56$

$p_l = \text{Area\_Tot\_Long\_Rein} / (b \cdot d) = 0.01639493$

$b = 450.00$

$d = 907.00$

$f_{cE} = 33.00$

End Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1

At local axis: 3

Integration Section: (a)

## Calculation No. 13

column C1, Floor 1

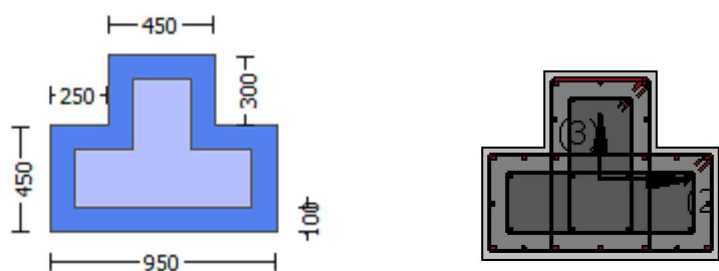
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JTC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Secondary 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

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

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

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $E_{cc} = 250.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length, L = 3000.00  
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_o = l_b = 300.00$   
 No FRP Wrapping

#### Stepwise Properties

EDGE -A-  
 Bending Moment,  $M_a = -2.9148E+007$   
 Shear Force,  $V_a = -9644.583$   
 EDGE -B-  
 Bending Moment,  $M_b = 209031.971$   
 Shear Force,  $V_b = 9644.583$   
 BOTH EDGES  
 Axial Force,  $F = -21706.813$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{st} = 0.00$   
   -Compression:  $A_{sc} = 6691.592$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{st,ten} = 1539.38$   
   -Compression:  $A_{sc,com} = 1539.38$   
   -Middle:  $A_{st,mid} = 3612.832$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.57143$

New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 1.4321E+006$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{CoI} = 1.4321E+006$   
 $V_{CoI} = 1.4321E+006$   
 $k_n = 1.00$   
 displacement\_ductility\_demand = 0.08512187

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:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 25.00$ , but  $f_c'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/V_d = 2.00$   
 $M_u = 209031.971$   
 $V_u = 9644.583$   
 $d = 0.8 \cdot h = 760.00$   
 $N_u = 21706.813$   
 $A_g = 427500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 1.0003E+006$   
 where:  
 $V_{sjacket} = V_{sj1} + V_{sj2} = 879645.943$   
 $V_{sj1} = 282743.339$  is calculated for section web jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{sj1}$  is multiplied by  $Col_{j1} = 1.00$   
 $s/d = 0.27777778$   
 $V_{sj2} = 596902.604$  is calculated for section flange jacket, with:  
 $d = 760.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{sj2}$  is multiplied by  $Col_{j2} = 1.00$   
 $s/d = 0.13157895$

$V_{s,c1} = V_{s,c1} + V_{s,c2} = 120637.158$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 500.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.25$   
 $V_{s,c2} = 120637.158$  is calculated for section flange core, with:  
 $d = 600.00$   
 $A_v = 100530.965$   
 $f_y = 500.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.41666667$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 1.1360E+006$   
 $bw = 450.00$

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

- Calculation of  $\phi / y$  for END B -  
for rotation axis 3 and integ. section (b)

From analysis, chord rotation  $\theta = 1.5891651E-005$   
 $y = (M_y * L_s / 3) / \phi_{eff} = 0.00018669$  ((4.29), Biskinis Phd)  
 $M_y = 5.2064E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 300.00  
 From table 10.5, ASCE 41\_17:  $\phi_{eff} = factor * E_c * I_g = 2.7887E+014$   
 $factor = 0.30$   
 $A_g = 562500.00$   
 Mean concrete strength:  $f'_c = (f'_c\_jacket * Area\_jacket + f'_c\_core * Area\_core) / Area\_section = 33.00$   
 $N = 21706.813$   
 $E_c * I_g = E_c\_jacket * I_g\_jacket + E_c\_core * I_g\_core = 9.2958E+014$

Calculation of Yielding Moment  $M_y$

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

$y = \min(y_{ten}, y_{com})$   
 $y_{ten} = 1.7803962E-006$   
 with ((10.1), ASCE 41-17)  $f_y = \min(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 239.4634$   
 $d = 907.00$   
 $y = 0.25854434$   
 $A = 0.01661703$   
 $B = 0.0088082$   
 with  $pt = 0.0037716$   
 $pc = 0.0037716$   
 $pv = 0.00885172$   
 $N = 21706.813$   
 $b = 450.00$   
 $" = 0.04740904$   
 $y_{comp} = 9.4777698E-006$   
 with  $f_c = 33.00$   
 $E_c = 26999.444$   
 $y = 0.25592822$   
 $A = 0.01627407$   
 $B = 0.0085861$   
 with  $E_s = 200000.00$

Calculation of ratio  $I_b / I_d$



Lap Length:  $l_d/l_{d,min} = 0.20248702$

$l_b = 300.00$

$l_d = 1481.576$

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

$l_{d,min}$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (10.3.5, ASCE 41-17)

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 555.56$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.37392$

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

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

$s = \max(s_{external}, s_{internal}) = 250.00$

$n = 30.00$

End Of Calculation of Shear Capacity for element: column JTC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 14

column C1, Floor 1

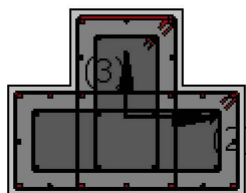
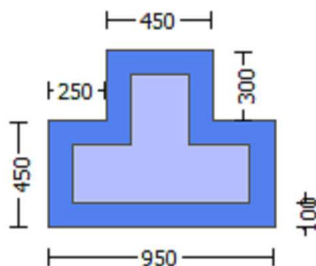
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\phi$ )

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjctcs

### Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $Ecc = 250.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.22443

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

No FRP Wrapping

### Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 4.6187021E-017$

EDGE -B-

Shear Force,  $V_b = -4.6187021E-017$

BOTH EDGES

Axial Force,  $F = -20792.022$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 6691.592$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 1539.38$

-Compression:  $As_{l,com} = 2475.575$

-Middle:  $As_{l,mid} = 2676.637$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.29138786$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 386950.491$

with

$$Mpr1 = \text{Max}(Mu1+, Mu1-) = 5.8043E+008$$

Mu1+ = 3.2937E+008, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

Mu1- = 5.8043E+008, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$$Mpr2 = \text{Max}(Mu2+, Mu2-) = 5.8043E+008$$

Mu2+ = 3.2937E+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- = 5.8043E+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:

$$\phi_u = 5.2477290E-006$$

$$Mu = 3.2937E+008$$

with full section properties:

$$b = 950.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093808$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01151713$$

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

$$\text{From (5.4b), TB DY: } \phi_u = 0.01151713$$

$$w_e (5.4c) = 0.04017143$$

$$a_{se} ((5.4d), \text{TB DY}) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53375773$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$$

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + psh2 * F_{ywe2} = 2.48363$$

$$psh1 ((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$$

$$L_{stir1} (\text{Length of stirrups along } Y) = 2160.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$psh2 (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$$

$$L_{stir2} (\text{Length of stirrups along } Y) = 1568.00$$

$$A_{stir2} (\text{stirrups area}) = 50.26548$$

$psh\_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$   
 $psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$   
 $L_{stir1} \text{ (Length of stirrups along X)} = 2560.00$   
 $A_{stir1} \text{ (stirrups area)} = 78.53982$   
 $psh2 ((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$   
 $L_{stir2} \text{ (Length of stirrups along X)} = 1968.00$   
 $A_{stir2} \text{ (stirrups area)} = 50.26548$

-----

$A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00424426$

$c = \text{confinement factor} = 1.22443$

$y1 = 0.00092863$

$sh1 = 0.00297161$

$ft1 = 309.5449$

$fy1 = 257.9541$

$su1 = 0.00297161$

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

$lo/lou, min = lb/ld = 0.16198962$

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

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  $fs1 = (fs_{jacket} * A_{sl, ten, jacket} + fs_{core} * A_{sl, ten, core}) / A_{sl, ten} = 257.9541$

with  $Es1 = (Es_{jacket} * A_{sl, ten, jacket} + Es_{core} * A_{sl, ten, core}) / A_{sl, ten} = 200000.00$

$y2 = 0.00092863$

$sh2 = 0.00297161$

$ft2 = 309.5449$

$fy2 = 257.9541$

$su2 = 0.00297161$

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

$lo/lou, min = lb/lb, min = 0.16198962$

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

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

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

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

with  $fs2 = (fs_{jacket} * A_{sl, com, jacket} + fs_{core} * A_{sl, com, core}) / A_{sl, com} = 257.9541$

with  $Es2 = (Es_{jacket} * A_{sl, com, jacket} + Es_{core} * A_{sl, com, core}) / A_{sl, com} = 200000.00$

$yv = 0.00092863$

$shv = 0.00297161$

$ftv = 309.5449$

$fyv = 257.9541$

$suv = 0.00297161$

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

$lo/lou, min = lb/ld = 0.16198962$

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

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  $fsv = (fs_{jacket} * A_{sl, mid, jacket} + fs_{mid} * A_{sl, mid, core}) / A_{sl, mid} = 257.9541$

with  $Esv = (Es_{jacket} * A_{sl, mid, jacket} + Es_{mid} * A_{sl, mid, core}) / A_{sl, mid} = 200000.00$

$1 = A_{sl, ten} / (b * d) * (fs1 / fc) = 0.0179156$

$2 = A_{sl, com} / (b * d) * (fs2 / fc) = 0.02881122$

$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03115121$   
 and confined core properties:  
 $b = 890.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.01997081$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.03211633$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03472476$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.19905879$   
 $Mu = MRc (4.14) = 3.2937E+008$   
 $u = su (4.1) = 5.2477290E-006$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.16198962$   
 $l_b = 300.00$   
 $l_d = 1851.971$   
 Calculation of  $l_b,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $l_d,min$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 694.45$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$   
 $n = 30.00$

Calculation of  $Mu1$ -

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 5.5327066E-006$   
 $Mu = 5.8043E+008$

with full section properties:

$b = 450.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00198039$   
 $N = 20792.022$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01151713$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01151713$   
 $we (5.4c) = 0.04017143$   
 $ase ((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53375773$   
 $ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max1 = 464100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 395025.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 173066.667 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.53375773$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 252164.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 111441.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 110709.333 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 2.48363$

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 2.48363

psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.00301593$

Lstir1 (Length of stirrups along Y) = 2160.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00056047$

Lstir2 (Length of stirrups along Y) = 1568.00

Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 2.97078

psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.00357443$

Lstir1 (Length of stirrups along X) = 2560.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00070345$

Lstir2 (Length of stirrups along X) = 1968.00

Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

using (30) in Biskinis/Fardis (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 = 0.16198962

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

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.

with fs1 =  $(f_{s,\text{jacket}} * A_{s,\text{ten,jacket}} + f_{s,\text{core}} * A_{s,\text{ten,core}}) / A_{s,\text{ten}} = 257.9541$

with Es1 =  $(E_{s,\text{jacket}} * A_{s,\text{ten,jacket}} + E_{s,\text{core}} * A_{s,\text{ten,core}}) / A_{s,\text{ten}} = 200000.00$

y2 = 0.00092863

sh2 = 0.00297161

```

ft2 = 309.5449
fy2 = 257.9541
su2 = 0.00297161
    using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
    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 = 257.9541
    with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
    yv = 0.00092863
    shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 0.16198962
    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 = 257.9541
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.06082368
    2 = Asl,com/(b*d)*(fs2/fc) = 0.03782183
    v = Asl,mid/(b*d)*(fsv/fc) = 0.06576367
and confined core properties:
    b = 390.00
    d = 677.00
    d' = 13.00
    fcc (5A.2, TBDY) = 40.40604
    cc (5A.5, TBDY) = 0.00424426
    c = confinement factor = 1.22443
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.07329111
    2 = Asl,com/(b*d)*(fs2/fc) = 0.04557442
    v = Asl,mid/(b*d)*(fsv/fc) = 0.07924369
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

```

```

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

```

```

su (4.9) = 0.24031351
Mu = MRc (4.14) = 5.8043E+008
u = su (4.1) = 5.5327066E-006

```

Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.16198962
lb = 300.00
lb = 1851.971

```

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
lb,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

```

= 1
db = 16.66667
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, but fc'^0.5 <= 8.3
MPa (22.5.3.1, ACI 318-14)
t = 1.00

```

$s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$   
 where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$   
 $n = 30.00$

Calculation of  $\mu_{2+}$

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

$\mu = 5.2477290\text{E-}006$   
 $\mu_u = 3.2937\text{E+}008$

with full section properties:

$b = 950.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00093808$   
 $N = 20792.022$   
 $f_c = 33.00$   
 $\alpha_0 (5A.5, \text{TB DY}) = 0.002$

Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \mu_c) = 0.01151713$

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

From (5.4b), TB DY:  $\mu_u = 0.01151713$

we (5.4c) = 0.04017143

$\alpha_{se} ((5.4d), \text{TB DY}) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.53375773$

$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\alpha_{se2} (> \alpha_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1} ((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$



$psh1 ((5.4d), TBDY) = Lstir1 * Astir1 / (Asec * s1) = 0.00357443$   
 $Lstir1$  (Length of stirrups along X) = 2560.00  
 $Astir1$  (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = Lstir2 * Astir2 / (Asec * s2) = 0.00070345$   
 $Lstir2$  (Length of stirrups along X) = 1968.00  
 $Astir2$  (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

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

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

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

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 257.9541

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

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

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

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

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

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 257.9541

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

yv = 0.00092863

shv = 0.00297161

ftv = 309.5449

fyv = 257.9541

suv = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

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  $\text{Min}(1, 1.25 * (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 257.9541

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0179156

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.02881122

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.03115121

and confined core properties:

$$b = 890.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc(5A.2, TBDY) = 40.40604$$

$$cc(5A.5, TBDY) = 0.00424426$$

$$c = \text{confinement factor} = 1.22443$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.01997081$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.03211633$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03472476$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

$$s_u(4.9) = 0.19905879$$

$$M_u = M_{Rc}(4.14) = 3.2937E+008$$

$$u = s_u(4.1) = 5.2477290E-006$$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.16198962$

$$l_b = 300.00$$

$$l_d = 1851.971$$

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

$l_d, \min$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 694.45$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.37392$$

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

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

$$s = \max(s_{external}, s_{internal}) = 250.00$$

$$n = 30.00$$

Calculation of  $M_{u2}$ -

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

$$u = 5.5327066E-006$$

$$M_u = 5.8043E+008$$

with full section properties:

$$b = 450.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00198039$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \max(c_u, c_o) = 0.01151713$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01151713$$

$$w_e(5.4c) = 0.04017143$$

$$a_{se}((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53375773$$

$$a_{se1} = \max(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00424426$

$c$  = confinement factor = 1.22443

$y1 = 0.00092863$

$sh1 = 0.00297161$

$ft1 = 309.5449$

$fy1 = 257.9541$

$su1 = 0.00297161$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lo_{min} = lb/ld = 0.16198962$

$su1 = 0.4 * esu1_{nominal}$  ((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  $fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 257.9541$

with  $Es1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.00092863$

$sh2 = 0.00297161$

$ft2 = 309.5449$

```

fy2 = 257.9541
su2 = 0.00297161
    using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
    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 = 257.9541
    with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
    yv = 0.00092863
    shv = 0.00297161
    ftv = 309.5449
    fyv = 257.9541
    suv = 0.00297161
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 0.16198962
    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 = 257.9541
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.06082368
    2 = Asl,com/(b*d)*(fs2/fc) = 0.03782183
    v = Asl,mid/(b*d)*(fsv/fc) = 0.06576367
    and confined core properties:
    b = 390.00
    d = 677.00
    d' = 13.00
    fcc (5A.2, TBDY) = 40.40604
    cc (5A.5, TBDY) = 0.00424426
    c = confinement factor = 1.22443
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.07329111
    2 = Asl,com/(b*d)*(fs2/fc) = 0.04557442
    v = Asl,mid/(b*d)*(fsv/fc) = 0.07924369

```

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

```

---->
v < vs,y2 - LHS eq.(4.5) is satisfied
---->
su (4.9) = 0.24031351
Mu = MRc (4.14) = 5.8043E+008
u = su (4.1) = 5.5327066E-006

```

#### Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.16198962
lb = 300.00
lb = 1851.971
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
lb,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, but fc'^0.5 <= 8.3
MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80

```

$e = 1.00$   
 $cb = 25.00$   
 $Ktr = 1.37392$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$   
 $n = 30.00$

---

Calculation of Shear Strength  $Vr = \text{Min}(Vr1, Vr2) = 1.3280E+006$

---

Calculation of Shear Strength at edge 1,  $Vr1 = 1.3280E+006$   
 $Vr1 = VCol \text{ ((10.3), ASCE 41-17)} = knl * VCol0$   
 $VCol0 = 1.3280E+006$   
 $knl = 1$  (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:  $fc' = (fc'_{\text{jacket}} * Area_{\text{jacket}} + fc'_{\text{core}} * Area_{\text{core}}) / Area_{\text{section}} = 33.00$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $Mu = 1534.054$   
 $Vu = 4.6187021E-017$   
 $d = 0.8 * h = 600.00$   
 $Nu = 20792.022$   
 $Ag = 337500.00$   
 From (11.5.4.8), ACI 318-14:  $Vs = Vs_{\text{jacket}} + Vs_{\text{core}} = 936062.473$   
 where:  
 $Vs_{\text{jacket}} = Vs_{j1} + Vs_{j2} = 837764.743$   
 $Vs_{j1} = 523602.964$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $Av = 157079.633$   
 $fy = 555.56$   
 $s = 100.00$   
 $Vs_{j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.16666667$   
 $Vs_{j2} = 314161.779$  is calculated for section flange jacket, with:  
 $d = 360.00$   
 $Av = 157079.633$   
 $fy = 555.56$   
 $s = 100.00$   
 $Vs_{j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.27777778$   
 $Vs_{\text{core}} = Vs_{c1} + Vs_{c2} = 98297.73$   
 $Vs_{c1} = 98297.73$  is calculated for section web core, with:  
 $d = 440.00$   
 $Av = 100530.965$   
 $fy = 555.56$   
 $s = 250.00$   
 $Vs_{c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $Vs_{c2} = 0.00$  is calculated for section flange core, with:  
 $d = 200.00$   
 $Av = 100530.965$   
 $fy = 555.56$   
 $s = 250.00$   
 $Vs_{c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.25$   
 $Vf \text{ ((11-3)-(11.4), ACI 440)} = 0.00$   
 From (11-11), ACI 440:  $Vs + Vf \leq 1.0304E+006$   
 $bw = 450.00$

---

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.3280E+006$

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

$V_{Col0} = 1.3280E+006$

$knl = 1$  (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:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 1534.054$

$V_u = 4.6187021E-017$

$d = 0.8 * h = 600.00$

$N_u = 20792.022$

$A_g = 337500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 936062.473$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 837764.743$

$V_{sj1} = 523602.964$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{sj1}$  is multiplied by  $Col_{j1} = 1.00$

$s/d = 0.16666667$

$V_{sj2} = 314161.779$  is calculated for section flange jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{sj2}$  is multiplied by  $Col_{j2} = 1.00$

$s/d = 0.27777778$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col_{c1} = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col_{c2} = 0.00$

$s/d = 1.25$

$V_f ((11-3)-(11.4), ACI 440) = 0.00$

From (11-11), ACI 440:  $V_s + V_f \leq 1.0304E+006$

$bw = 450.00$

End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\phi = 1.00$   
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Jacket  
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
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  
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
#####  
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 450.00$   
Max Width,  $W_{max} = 950.00$   
Min Width,  $W_{min} = 450.00$   
Eccentricity,  $E_{cc} = 250.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.22443  
Element Length,  $L = 3000.00$   
Secondary Member  
Smooth Bars  
Ductile Steel  
With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = 300.00$   
No FRP Wrapping

#### Stepwise Properties

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = 1.3499588E-021$   
EDGE -B-  
Shear Force,  $V_b = -1.3499588E-021$   
BOTH EDGES  
Axial Force,  $F = -20792.022$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{sl,t} = 0.00$   
-Compression:  $A_{sl,c} = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten} = 1539.38$   
-Compression:  $A_{sl,com} = 1539.38$   
-Middle:  $A_{sl,mid} = 3612.832$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.22515134$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 361758.676$   
with  
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 5.4264E+008$   
 $M_{u1+} = 5.4264E+008$ , 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  
 $M_{u1-} = 5.4264E+008$ , 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

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 5.4264\text{E}+008$$

$M_{u2+} = 5.4264\text{E}+008$ , 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

$M_{u2-} = 5.4264\text{E}+008$ , 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  $M_{u1+}$

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

$$\phi_u = 4.1882964\text{E}-006$$

$$M_u = 5.4264\text{E}+008$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$\nu = 0.0015437$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_{cu}^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01151713$$

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

$$\text{From (5.4b), TB DY: } \phi_{cu} = 0.01151713$$

$$\text{we (5.4c)} = 0.04017143$$

$$\phi_{ase} ((5.4d), \text{TB DY}) = (\phi_{ase1} * A_{ext} + \phi_{ase2} * A_{int}) / A_{sec} = 0.53375773$$

$$\phi_{ase1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\phi_{ase2} (>= \phi_{ase1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$$

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$$

$$p_{sh1} ((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$$

$$L_{stir1} (\text{Length of stirrups along Y}) = 2160.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$p_{sh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$$

$$L_{stir2} (\text{Length of stirrups along Y}) = 1568.00$$

$$A_{stir2} (\text{stirrups area}) = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$$

$$p_{sh1} ((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$$

$$L_{stir1} (\text{Length of stirrups along X}) = 2560.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$



$psh2 ((5.4d), TBDY) = Lstir2 * Astir2 / (Asec * s2) = 0.00070345$   
 $Lstir2 (\text{Length of stirrups along X}) = 1968.00$   
 $Astir2 (\text{stirrups area}) = 50.26548$

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962

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 = 257.9541

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

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

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 = 257.9541

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

yv = 0.00092863

shv = 0.00297161

ftv = 309.5449

fyv = 257.9541

suv = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962

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 = 257.9541

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.02948185

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.02948185

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.06919209

and confined core properties:

b = 390.00

d = 877.00

$d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03518117$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.03518117$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08256805$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.21774786$   
 $Mu = MRc (4.14) = 5.4264E+008$   
 $u = su (4.1) = 4.1882964E-006$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.16198962$   
 $l_b = 300.00$   
 $l_d = 1851.971$   
 Calculation of  $l_b$ ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $l_d$ ,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 694.45$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$   
 $n = 30.00$

Calculation of  $Mu1$ -

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 4.1882964E-006$   
 $Mu = 5.4264E+008$

with full section properties:

$b = 450.00$   
 $d = 907.00$   
 $d' = 43.00$   
 $v = 0.0015437$   
 $N = 20792.022$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01151713$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01151713$   
 $we (5.4c) = 0.04017143$   
 $ase ((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53375773$   
 $ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)  
 "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max1 = 464100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
Aconf,min1 = 395025.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 173066.667 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.53375773$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 252164.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 111441.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 110709.333 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 2.48363$

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 2.48363  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00301593$   
Lstir1 (Length of stirrups along Y) = 2160.00  
Astir1 (stirrups area) = 78.53982  
psh2 (5.4d) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00056047$   
Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 2.97078  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00357443$   
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00070345$   
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

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

lo/lou,min =  $l_b/l_d = 0.16198962$

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

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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 257.9541$

with Es1 =  $(E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.16198962$   
 $su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$   
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  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 257.9541$   
with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.00092863$   
 $sh_v = 0.00297161$   
 $ft_v = 309.5449$   
 $fy_v = 257.9541$   
 $suv = 0.00297161$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.16198962$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
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  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 257.9541$   
with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.02948185$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.02948185$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.06919209$   
and confined core properties:  
 $b = 390.00$   
 $d = 877.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.03518117$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.03518117$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.08256805$   
Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)  
--->  
 $v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied  
--->  
 $su (4.9) = 0.21774786$   
 $Mu = MRc (4.14) = 5.4264E+008$   
 $u = su (4.1) = 4.1882964E-006$   
-----  
Calculation of ratio  $l_b/l_d$   
-----  
Lap Length:  $l_b/l_d = 0.16198962$   
 $l_b = 300.00$   
 $l_d = 1851.971$   
Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $l_{d,min}$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
 $= 1$   
 $db = 16.66667$   
Mean strength value of all re-bars:  $fy = 694.45$   
Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $fc'^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$

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

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 30.00$$

Calculation of  $\mu_{2+}$

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

$$\mu = 4.1882964\text{E-}006$$

$$\mu_{\mu} = 5.4264\text{E+}008$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_{\text{cu}} = \text{shear\_factor} * \text{Max}(\phi_{\text{cu}}, \phi_{\text{cc}}) = 0.01151713$$

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

$$\text{From (5.4b), TBDY: } \phi_{\text{cu}} = 0.01151713$$

$$\text{we (5.4c)} = 0.04017143$$

$$\text{ase ((5.4d), TBDY)} = (\text{ase1} * A_{\text{ext}} + \text{ase2} * A_{\text{int}}) / A_{\text{sec}} = 0.53375773$$

$$\text{ase1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.53375773$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\text{ase2} (>= \text{ase1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.53375773$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max2}} = 252164.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{\text{conf,min2}} = 111441.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{\text{conf,max2}}$  by a length equal to half the clear spacing between internal hoops.

$A_{\text{noConf2}} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\text{psh,min} * F_{ywe} = \text{Min}(\text{psh,x} * F_{ywe}, \text{psh,y} * F_{ywe}) = 2.48363$$

$$\text{psh}_x * F_{ywe} = \text{psh1} * F_{ywe1} + \text{ps2} * F_{ywe2} = 2.48363$$

$$\text{psh1 ((5.4d), TBDY)} = L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.00301593$$

$$L_{\text{stir1}} (\text{Length of stirrups along Y}) = 2160.00$$

$$A_{\text{stir1}} (\text{stirrups area}) = 78.53982$$

$$\text{psh2 (5.4d)} = L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00056047$$

$$L_{\text{stir2}} (\text{Length of stirrups along Y}) = 1568.00$$

$$A_{\text{stir2}} (\text{stirrups area}) = 50.26548$$

$$\text{psh}_y * F_{ywe} = \text{psh1} * F_{ywe1} + \text{ps2} * F_{ywe2} = 2.97078$$

$$\text{psh1 ((5.4d), TBDY)} = L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.00357443$$

$$L_{\text{stir1}} (\text{Length of stirrups along X}) = 2560.00$$

$$A_{\text{stir1}} (\text{stirrups area}) = 78.53982$$

$$\text{psh2 ((5.4d), TBDY)} = L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00070345$$

Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00  
s1 = 100.00  
s2 = 250.00  
fywe1 = 694.45  
fywe2 = 694.45  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426  
c = confinement factor = 1.22443

y1 = 0.00092863  
sh1 = 0.00297161  
ft1 = 309.5449  
fy1 = 257.9541  
su1 = 0.00297161

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

lo/lou,min = lb/lb = 0.16198962  
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 = 257.9541

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

y2 = 0.00092863  
sh2 = 0.00297161  
ft2 = 309.5449  
fy2 = 257.9541  
su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962  
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 = 257.9541

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

yv = 0.00092863  
shv = 0.00297161  
ftv = 309.5449  
fyv = 257.9541  
suv = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962  
suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

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

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

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

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

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 257.9541

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.02948185

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.02948185

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.06919209

and confined core properties:

b = 390.00  
d = 877.00  
d' = 13.00

```

fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.03518117
2 = Asl,com/(b*d)*(fs2/fc) = 0.03518117
v = Asl,mid/(b*d)*(fsv/fc) = 0.08256805
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.21774786
Mu = MRc (4.14) = 5.4264E+008
u = su (4.1) = 4.1882964E-006

```

#### Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.16198962
lb = 300.00
ld = 1851.971
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
ld,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, 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 = 1.37392
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) = 250.00
n = 30.00

```

#### Calculation of Mu2-

```

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 4.1882964E-006
Mu = 5.4264E+008

```

#### with full section properties:

```

b = 450.00
d = 907.00
d' = 43.00
v = 0.0015437
N = 20792.022
fc = 33.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01151713
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01151713
we (5.4c) = 0.04017143
ase ((5.4d), TBDY) = (ase1*Aext+ase2*Aint)/Asec = 0.53375773
ase1 = Max(((Aconf,max1-AnoConf1)/Aconf,max1)*(Aconf,min1/Aconf,max1),0) = 0.53375773
The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization
of the rectangular sections confinement, which is expressed by (5.4d).
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)
"Theoretical Stress-Strain Model for Confined Concrete."
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

```

Aconf,max1 = 464100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
Aconf,min1 = 395025.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 173066.667 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.53375773$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 252164.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 111441.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 110709.333 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 2.48363$

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 2.48363  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.00301593$   
Lstir1 (Length of stirrups along Y) = 2160.00  
Astir1 (stirrups area) = 78.53982  
psh2 (5.4d) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00056047$   
Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 2.97078  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.00357443$   
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00070345$   
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

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

lo/lou,min =  $l_b/l_d = 0.16198962$

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

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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 257.9541$

with Es1 =  $(E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.02948185
2 = Asl,com/(b*d)*(fs2/fc) = 0.02948185
v = Asl,mid/(b*d)*(fsv/fc) = 0.06919209
and confined core properties:
b = 390.00
d = 877.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.03518117
2 = Asl,com/(b*d)*(fs2/fc) = 0.03518117
v = Asl,mid/(b*d)*(fsv/fc) = 0.08256805
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.21774786
Mu = MRc (4.14) = 5.4264E+008
u = su (4.1) = 4.1882964E-006
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.16198962
lb = 300.00
ld = 1851.971
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
ld,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, 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 = 1.37392
Atr = Min(Atr_x,Atr_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  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$   
 $n = 30.00$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.6067\text{E}+006$

Calculation of Shear Strength at edge 1,  $V_{r1} = 1.6067\text{E}+006$

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

$V_{\text{ColO}} = 1.6067\text{E}+006$

$\text{knl} = 1$  (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:  $f'_c = (f'_{c\_jacket} * \text{Area}_{jacket} + f'_{c\_core} * \text{Area}_{core}) / \text{Area}_{\text{section}} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.04067$

$V_u = 1.3499588\text{E}-021$

$d = 0.8 * h = 760.00$

$N_u = 20792.022$

$A_g = 427500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 1.1114\text{E}+006$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 977392.20$

$V_{s,j1} = 314161.779$  is calculated for section web jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 1.00$

$s/d = 0.27777778$

$V_{s,j2} = 663230.422$  is calculated for section flange jacket, with:

$d = 760.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 1.00$

$s/d = 0.13157895$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 0.00$

$s/d = 1.25$

$V_{s,c2} = 134042.359$  is calculated for section flange core, with:

$d = 600.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 1.00$

$s/d = 0.41666667$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 0.00$

From (11-11), ACI 440:  $V_s + V_f \leq 1.3051\text{E}+006$

$b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.6067\text{E}+006$

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

$V_{\text{ColO}} = 1.6067\text{E}+006$

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

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

= 1 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.04067$

$V_u = 1.3499588E+021$

$d = 0.8 \cdot h = 760.00$

$N_u = 20792.022$

$A_g = 427500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 1.1114E+006$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 977392.20$

$V_{s,j1} = 314161.779$  is calculated for section web jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$

$s/d = 0.27777778$

$V_{s,j2} = 663230.422$  is calculated for section flange jacket, with:

$d = 760.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$s/d = 0.13157895$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$

$s/d = 1.25$

$V_{s,c2} = 134042.359$  is calculated for section flange core, with:

$d = 600.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$

$s/d = 0.41666667$

$V_f$  ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440:  $V_s + V_f \leq 1.3051E+006$

$b_w = 450.00$

End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 450.00$   
 Max Width,  $W_{max} = 950.00$   
 Min Width,  $W_{min} = 450.00$   
 Eccentricity,  $E_{cc} = 250.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_b = 300.00$   
 No FRP Wrapping

#### Stepwise Properties

Bending Moment,  $M = -112664.662$   
 Shear Force,  $V_2 = 9644.583$   
 Shear Force,  $V_3 = -108.1943$   
 Axial Force,  $F = -21706.813$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{st} = 0.00$   
   -Compression:  $A_{sc} = 6691.592$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{st,ten} = 1539.38$   
   -Compression:  $A_{st,com} = 2475.575$   
   -Middle:  $A_{st,mid} = 2676.637$   
 Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{st,ten,jacket} = 1231.504$   
   -Compression:  $A_{st,com,jacket} = 1859.823$   
   -Middle:  $A_{st,mid,jacket} = 2060.885$   
 Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{st,ten,core} = 307.8761$   
   -Compression:  $A_{st,com,core} = 615.7522$   
   -Middle:  $A_{st,mid,core} = 615.7522$   
 Mean Diameter of Tension Reinforcement,  $Db_L = 16.57143$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = 1.0^*$   $u = 0.0239252$   
 $u = y + p = 0.0239252$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.0007168$  ((4.29), Biskinis Phd))  
 $M_y = 3.7894E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 1041.318  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.8350E+014$   
 $factor = 0.30$   
 $A_g = 562500.00$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$   
 $N = 21706.813$

$$E_c I_g = E_{c\_jacket} I_{g\_jacket} + E_{c\_core} I_{g\_core} = 6.1166E+014$$

Calculation of Yielding Moment  $M_y$

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

Assuming neutral axis within flange ( $\rho_y < t/d$ , compression zone rectangular) with:

flange width,  $b = 950.00$

web width,  $b_w = 450.00$

flange thickness,  $t = 450.00$

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

$$y_{\text{ten}} = 2.1201278E-006$$

$$\text{with } ((10.1), \text{ASCE 41-17}) f_y = \text{Min}(f_y, 1.25 * f_y * (I_b/I_d)^{2/3}) = 239.4634$$

$$d = 707.00$$

$$y = 0.20121911$$

$$A = 0.01009788$$

$$B = 0.00476485$$

$$\text{with } p_t = 0.00229194$$

$$p_c = 0.00368581$$

$$p_v = 0.00398517$$

$$N = 21706.813$$

$$b = 950.00$$

$$\rho_y = 0.06082037$$

$$y_{\text{comp}} = 1.5661056E-005$$

$$\text{with } f_c = 33.00$$

$$E_c = 26999.444$$

$$y = 0.19869693$$

$$A = 0.00988947$$

$$B = 0.00462988$$

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

$$\text{CONFIRMATION: } \rho_y = 0.19956461 < t/d$$

Calculation of ratio  $I_b/I_d$

$$\text{Lap Length: } I_d/I_{d,\text{min}} = 0.20248702$$

$$I_b = 300.00$$

$$I_d = 1481.576$$

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

$I_{d,\text{min}}$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (10.3.5, ASCE 41-17)

$$= 1$$

$$d_b = 16.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 555.56$$

$$\text{Mean concrete strength: } f'_c = (f'_{c\_jacket} * \text{Area}_{\text{jacket}} + f'_{c\_core} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00, \text{ but } f'_c^{0.5} \leq 8.3$$

MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.37392$$

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

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 30.00$$

- Calculation of  $\rho_p$  -

$$\text{From table 10-8: } \rho_p = 0.0232084$$

with:

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

$$\text{shear control ratio } V_y/E/V_{colOE} = 0.29138786$$

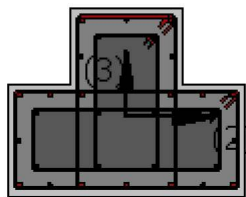
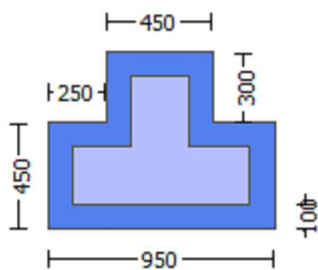
$$d = d_{\text{external}} = 707.00$$

$s = s_{\text{external}} = 0.00$   
 $t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.0035764$   
 jacket:  $s_1 = A_{v1} \cdot L_{\text{stir1}} / (s_1 \cdot A_g) = 0.00301593$   
 $A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction  
 $L_{\text{stir1}} = 2160.00$ , is the total Length of all stirrups parallel to loading (shear) direction  
 $s_1 = 100.00$   
 core:  $s_2 = A_{v2} \cdot L_{\text{stir2}} / (s_2 \cdot A_g) = 0.00056047$   
 $A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction  
 $L_{\text{stir2}} = 1568.00$ , is the total Length of all stirrups parallel to loading (shear) direction  
 $s_2 = 250.00$   
 The term  $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$  is implemented to account for FRP contribution  
 where  $f = 2 \cdot t_f / b_w$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength  
 All these variables have already been given in Shear control ratio calculation.  
 For the normalisation  $f_s$  of jacket is used.  
 $NUD = 21706.813$   
 $A_g = 562500.00$   
 $f_{cE} = (f_{c\_jacket} \cdot \text{Area\_jacket} + f_{c\_core} \cdot \text{Area\_core}) / \text{section\_area} = 33.00$   
 $f_{yE} = (f_{y\_ext\_Long\_Reinf} \cdot \text{Area\_ext\_Long\_Reinf} + f_{y\_int\_Long\_Reinf} \cdot \text{Area\_int\_Long\_Reinf}) / \text{Area\_Tot\_Long\_Rein} = 555.56$   
 $f_{yE} = (f_{y\_ext\_Trans\_Reinf} \cdot s_1 + f_{y\_int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 555.56$   
 $\rho_l = \text{Area\_Tot\_Long\_Rein} / (b \cdot d) = 0.00996292$   
 $b = 950.00$   
 $d = 707.00$   
 $f_{cE} = 33.00$

-----  
 End Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1  
 At local axis: 2  
 Integration Section: (b)  
 -----

## Calculation No. 15

column C1, Floor 1  
 Limit State: Life Safety (data interpolation between analysis steps 1 and 2)  
 Analysis: Uniform +X  
 Check: Shear capacity  $V_{Rd}$   
 Edge: End  
 Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JTC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Secondary 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

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

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

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $Ecc = 250.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = l_b = 300.00$

No FRP Wrapping

Stepwise Properties

EDGE -A-

Bending Moment,  $M_a = -210804.16$   
 Shear Force,  $V_a = 108.1943$   
 EDGE -B-  
 Bending Moment,  $M_b = -112664.662$   
 Shear Force,  $V_b = -108.1943$   
 BOTH EDGES  
 Axial Force,  $F = -21706.813$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{st} = 0.00$   
   -Compression:  $A_{sc} = 6691.592$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{sl,ten} = 1539.38$   
   -Compression:  $A_{sl,com} = 2475.575$   
   -Middle:  $A_{sl,mid} = 2676.637$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.57143$

New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 1.1843E+006$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n I \cdot V_{ColO} = 1.1843E+006$   
 $V_{Col} = 1.1843E+006$   
 $k_n I = 1.00$   
 displacement\_ductility\_demand =  $6.1066038E-007$

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:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 25.00$ , but  $f'_c^{0.5} \leq 8.3$   
 MPa ((22.5.3.1, ACI 318-14))  
 $M/Vd = 2.00$   
 $M_u = 112664.662$   
 $V_u = 108.1943$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 21706.813$   
 $A_g = 337500.00$   
 From ((11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 842449.486$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 753982.237$   
 $V_{s,j1} = 471238.898$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col_{j1} = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 282743.339$  is calculated for section flange jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col_{j2} = 1.00$   
 $s/d = 0.27777778$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 88467.249$   
 $V_{s,c1} = 88467.249$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 500.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col_{c1} = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 500.00$   
 $s = 250.00$



$V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.25$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 896810.169$   
 $bw = 450.00$

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

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

From analysis, chord rotation  $\theta = 4.3772035E-010$   
 $y = (M_y * L_s / 3) / E_{eff} = 0.0007168 ((4.29), Biskinis Phd)$   
 $M_y = 3.7894E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 1041.318  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.8350E+014$   
 $factor = 0.30$   
 $A_g = 562500.00$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$   
 $N = 21706.813$   
 $E_c * I_g = E_c_{jacket} * I_{g,jacket} + E_c_{core} * I_{g,core} = 6.1166E+014$

Calculation of Yielding Moment  $M_y$

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

Assuming neutral axis within flange ( $\phi_y < t/d$ , compression zone rectangular) with:  
 flange width,  $b = 950.00$   
 web width,  $bw = 450.00$   
 flange thickness,  $t = 450.00$

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 2.1201278E-006$   
 with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 239.4634$   
 $d = 707.00$   
 $y = 0.20121911$   
 $A = 0.01009788$   
 $B = 0.00476485$   
 with  $pt = 0.00229194$   
 $pc = 0.00368581$   
 $pv = 0.00398517$   
 $N = 21706.813$   
 $b = 950.00$   
 $" = 0.06082037$   
 $y_{comp} = 1.5661056E-005$   
 with  $f_c = 33.00$   
 $E_c = 26999.444$   
 $y = 0.19869693$   
 $A = 0.00988947$   
 $B = 0.00462988$   
 with  $E_s = 200000.00$   
 CONFIRMATION:  $\phi_y = 0.19956461 < t/d$

Calculation of ratio  $I_b / I_d$

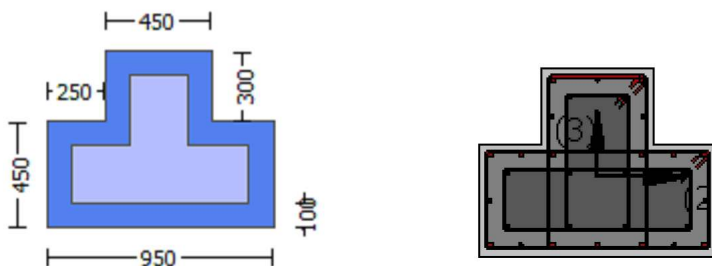
Lap Length:  $I_d / I_{d,min} = 0.20248702$   
 $I_b = 300.00$   
 $I_d = 1481.576$   
 Calculation of  $I$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $I_{d,min}$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (10.3.5, ASCE 41-17)  
 $= 1$

$db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 555.56$   
 Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$   
 where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$   
 $n = 30.00$

End Of Calculation of Shear Capacity for element: column JTC1 of floor 1  
 At local axis: 3  
 Integration Section: (b)

## Calculation No. 16

column C1, Floor 1  
 Limit State: Life Safety (data interpolation between analysis steps 1 and 2)  
 Analysis: Uniform +X  
 Check: Chord rotation capacity (  $\mu$  )  
 Edge: End  
 Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
 At Shear local axis: 3  
 (Bending local axis: 2)  
 Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:

```

Jacket
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$ 
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$ 
Concrete Elasticity,  $E_c = 26999.444$ 
Steel Elasticity,  $E_s = 200000.00$ 
Existing Column
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$ 
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$ 
Concrete Elasticity,  $E_c = 26999.444$ 
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
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$ 
#####
Max Height,  $H_{max} = 750.00$ 
Min Height,  $H_{min} = 450.00$ 
Max Width,  $W_{max} = 950.00$ 
Min Width,  $W_{min} = 450.00$ 
Eccentricity,  $Ecc = 250.00$ 
Jacket Thickness,  $t_j = 100.00$ 
Cover Thickness,  $c = 25.00$ 
Mean Confinement Factor overall section = 1.22443
Element Length,  $L = 3000.00$ 
Secondary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length  $l_o = 300.00$ 
No FRP Wrapping
-----

Stepwise Properties
-----
At local axis: 3
EDGE -A-
Shear Force,  $V_a = 4.6187021E-017$ 
EDGE -B-
Shear Force,  $V_b = -4.6187021E-017$ 
BOTH EDGES
Axial Force,  $F = -20792.022$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $As_t = 0.00$ 
-Compression:  $As_c = 6691.592$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension:  $As_{ten} = 1539.38$ 
-Compression:  $As_{com} = 2475.575$ 
-Middle:  $As_{mid} = 2676.637$ 
-----
-----

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.29138786$ 
Member Controlled by Flexure ( $V_e/V_r < 1$ )
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 386950.491$ 
with
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 5.8043E+008$ 
 $Mu_{1+} = 3.2937E+008$ , 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
 $Mu_{1-} = 5.8043E+008$ , 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
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 5.8043E+008$ 
 $Mu_{2+} = 3.2937E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction

```

which is defined for the the static loading combination

Mu2- = 5.8043E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu1+

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

$$\phi_u = 5.2477290E-006$$

$$M_u = 3.2937E+008$$

with full section properties:

$$b = 950.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$\nu = 0.00093808$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_o) = 0.01151713$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01151713$$

$$w_e \text{ (5.4c)} = 0.04017143$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53375773$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length

equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$$

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.48363$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2160.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1568.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.97078$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2560.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1968.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

```

Asec = 562500.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 694.45
fce = 33.00
From ((5.A.5), TBDY), TBDY: cc = 0.00424426
c = confinement factor = 1.22443
y1 = 0.00092863
sh1 = 0.00297161
ft1 = 309.5449
fy1 = 257.9541
su1 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 257.9541
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00092863
sh2 = 0.00297161
ft2 = 309.5449
fy2 = 257.9541
su2 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0179156
2 = Asl,com/(b*d)*(fs2/fc) = 0.02881122
v = Asl,mid/(b*d)*(fsv/fc) = 0.03115121
and confined core properties:
b = 890.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426

```

$c = \text{confinement factor} = 1.22443$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.01997081$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.03211633$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03472476$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su(4.9) = 0.19905879$   
 $Mu = MRc(4.14) = 3.2937E+008$   
 $u = su(4.1) = 5.2477290E-006$

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

Lap Length:  $l_b/l_d = 0.16198962$   
 $l_b = 300.00$   
 $l_d = 1851.971$   
 Calculation of  $l_b, \min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $l_d, \min$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 694.45$   
 Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}, A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \max(s_{external}, s_{internal}) = 250.00$   
 $n = 30.00$

#### Calculation of $Mu1$ -

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 5.5327066E-006$   
 $Mu = 5.8043E+008$

with full section properties:

$b = 450.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00198039$   
 $N = 20792.022$   
 $f_c = 33.00$   
 $\alpha(5A.5, TBDY) = 0.002$   
 Final value of  $cu^*$ :  $cu^* = \text{shear\_factor} * \max(cu, cc) = 0.01151713$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01151713$   
 $w_e(5.4c) = 0.04017143$   
 $ase((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53375773$   
 $ase1 = \max(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and  
 is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 395025.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 173066.667 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.53375773$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 252164.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 111441.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 110709.333 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 2.48363$

psh\_x\*Fywe =  $psh1 * Fywe1 + ps2 * Fywe2 = 2.48363$   
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00301593$   
Lstir1 (Length of stirrups along Y) = 2160.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d)) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00056047$   
Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe =  $psh1 * Fywe1 + ps2 * Fywe2 = 2.97078$   
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00357443$   
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00070345$   
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

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

lo/lou,min =  $l_b/l_d = 0.16198962$

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

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

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

with fs1 =  $(f_{s,\text{jacket}} * A_{s1,\text{ten,jacket}} + f_{s,\text{core}} * A_{s1,\text{ten,core}}) / A_{s1,\text{ten}} = 257.9541$

with Es1 =  $(E_{s,\text{jacket}} * A_{s1,\text{ten,jacket}} + E_{s,\text{core}} * A_{s1,\text{ten,core}}) / A_{s1,\text{ten}} = 200000.00$

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

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

lo/lou,min =  $l_b/l_{b,\text{min}} = 0.16198962$

$su_2 = 0.4 \cdot esu_{2\_nominal} ((5.5), TBDY) = 0.032$   
 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  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 257.9541$   
 with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.00092863$   
 $sh_v = 0.00297161$   
 $ft_v = 309.5449$   
 $fy_v = 257.9541$   
 $suv = 0.00297161$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{u,min} = lb/ld = 0.16198962$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 257.9541$   
 with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.06082368$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.03782183$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.06576367$

and confined core properties:

$b = 390.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.07329111$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.04557442$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.07924369$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.24031351$

$\mu_u = MR_c (4.14) = 5.8043E+008$

$u = su (4.1) = 5.5327066E-006$

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

-----  
 Lap Length:  $lb/ld = 0.16198962$

$lb = 300.00$

$ld = 1851.971$

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

$ld_{min}$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 694.45$

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.37392$

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

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

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$



$$n = 30.00$$

Calculation of  $\mu_{2+}$

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

$$\mu = 5.2477290E-006$$

$$\mu = 3.2937E+008$$

with full section properties:

$$b = 950.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093808$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, c_o) = 0.01151713$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01151713$$

$$\mu_e \text{ (5.4c)} = 0.04017143$$

$$\mu_{se} \text{ ((5.4d), TBDY)} = (\mu_{se1} * A_{ext} + \mu_{se2} * A_{int}) / A_{sec} = 0.53375773$$

$$\mu_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\mu_{se2} (>= \mu_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$$

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + psh2 * F_{ywe2} = 2.48363$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2160.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1568.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + psh2 * F_{ywe2} = 2.97078$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2560.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1968.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

```

Asec = 562500.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 694.45
fce = 33.00
From ((5.A.5), TBDY), TBDY: cc = 0.00424426
c = confinement factor = 1.22443
y1 = 0.00092863
sh1 = 0.00297161
ft1 = 309.5449
fy1 = 257.9541
su1 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 257.9541
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00092863
sh2 = 0.00297161
ft2 = 309.5449
fy2 = 257.9541
su2 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0179156
2 = Asl,com/(b*d)*(fs2/fc) = 0.02881122
v = Asl,mid/(b*d)*(fsv/fc) = 0.03115121
and confined core properties:
b = 890.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443

```

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.01997081$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.03211633$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03472476$$

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

---->

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

---->

$$s_u(4.9) = 0.19905879$$

$$M_u = M_{Rc}(4.14) = 3.2937E+008$$

$$u = s_u(4.1) = 5.2477290E-006$$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.16198962$

$$l_b = 300.00$$

$$l_d = 1851.971$$

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

$l_d$ ,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 694.45$

Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.37392$$

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

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

$$s = \max(s_{external}, s_{internal}) = 250.00$$

$$n = 30.00$$

Calculation of  $M_u2$ -

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

$$u = 5.5327066E-006$$

$$M_u = 5.8043E+008$$

with full section properties:

$$b = 450.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00198039$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \max(c_u, c_c) = 0.01151713$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01151713$$

$$\text{we (5.4c)} = 0.04017143$$

$$a_{se}((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53375773$$

$$a_{se1} = \max(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>=ase1) = \text{Max}(((A_{conf,max2}-A_{noConf2})/A_{conf,max2})*(A_{conf,min2}/A_{conf,max2}),0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 2.48363$

-----  
 $psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.48363$   
 $psh1 ((5.4d), TBDY) = Lstir1*Astir1/(Asec*s1) = 0.00301593$   
 $Lstir1$  (Length of stirrups along Y) = 2160.00  
 $Astir1$  (stirrups area) = 78.53982  
 $psh2 ((5.4d)) = Lstir2*Astir2/(Asec*s2) = 0.00056047$   
 $Lstir2$  (Length of stirrups along Y) = 1568.00  
 $Astir2$  (stirrups area) = 50.26548

-----  
 $psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.97078$   
 $psh1 ((5.4d), TBDY) = Lstir1*Astir1/(Asec*s1) = 0.00357443$   
 $Lstir1$  (Length of stirrups along X) = 2560.00  
 $Astir1$  (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = Lstir2*Astir2/(Asec*s2) = 0.00070345$   
 $Lstir2$  (Length of stirrups along X) = 1968.00  
 $Astir2$  (stirrups area) = 50.26548

-----  
 $Asec = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$fywe1 = 694.45$

$fywe2 = 694.45$

$fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00424426$

$c =$  confinement factor = 1.22443

$y1 = 0.00092863$

$sh1 = 0.00297161$

$ft1 = 309.5449$

$fy1 = 257.9541$

$su1 = 0.00297161$

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

Shear\_factor = 1.00

$lo/lou,min = lb/ld = 0.16198962$

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

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  $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 257.9541$

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

$y2 = 0.00092863$

$sh2 = 0.00297161$

$ft2 = 309.5449$

$fy2 = 257.9541$

$su2 = 0.00297161$

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

Shear\_factor = 1.00

$lo/lou,min = lb/lb,min = 0.16198962$

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

From table 5A.1, TBDY:  $es_{2\_nominal} = 0.08$ ,  
 For calculation of  $es_{2\_nominal}$  and  $y_2$ ,  $sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fs_{y2} = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 257.9541$   
 with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.00092863$   
 $sh_v = 0.00297161$   
 $ft_v = 309.5449$   
 $fy_v = 257.9541$   
 $suv = 0.00297161$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou_{min} = lb/d = 0.16198962$   
 $suv = 0.4 \cdot es_{uv\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $es_{uv\_nominal} = 0.08$ ,  
 considering characteristic value  $fs_{yv} = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $es_{uv\_nominal}$  and  $y_v$ ,  $sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fs_{yv} = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 257.9541$   
 with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.06082368$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.03782183$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.06576367$   
 and confined core properties:  
 $b = 390.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.07329111$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.04557442$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.07924369$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.24031351$   
 $Mu = MRc (4.14) = 5.8043E+008$   
 $u = su (4.1) = 5.5327066E-006$   
 -----  
 Calculation of ratio  $lb/d$   
 -----  
 Lap Length:  $lb/d = 0.16198962$   
 $lb = 300.00$   
 $ld = 1851.971$   
 Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $ld_{min}$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $fy = 694.45$   
 Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $fc'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$   
 where  $A_{tr\_x}, A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$   
 $n = 30.00$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.3280\text{E}+006$

Calculation of Shear Strength at edge 1,  $V_{r1} = 1.3280\text{E}+006$

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

$V_{\text{ColO}} = 1.3280\text{E}+006$

$\text{knl} = 1$  (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:  $f'_c = (f'_c_{\text{jacket}} * \text{Area}_{\text{jacket}} + f'_c_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 1534.054$

$V_u = 4.6187021\text{E}-017$

$d = 0.8 * h = 600.00$

$N_u = 20792.022$

$A_g = 337500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 936062.473$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 837764.743$

$V_{s,j1} = 523602.964$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 1.00$

$s/d = 0.27777778$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 0.00$

$s/d = 1.25$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 0.00$

From (11-11), ACI 440:  $V_s + V_f \leq 1.0304\text{E}+006$

$b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.3280\text{E}+006$

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

$V_{\text{ColO}} = 1.3280\text{E}+006$

$\text{knl} = 1$  (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:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1534.054$   
 $V_u = 4.6187021\text{E}-017$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 20792.022$   
 $A_g = 337500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 936062.473$   
 where:  
 $V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 837764.743$   
 $V_{s,j1} = 523602.964$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $\text{Col},j1 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $\text{Col},j2 = 1.00$   
 $s/d = 0.27777778$   
 $V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 98297.73$   
 $V_{s,c1} = 98297.73$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $\text{Col},c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $\text{Col},c2 = 0.00$   
 $s/d = 1.25$   
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 1.0304\text{E}+006$   
 $b_w = 450.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
 At local axis: 3

-----  
 Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
 At Shear local axis: 2  
 (Bending local axis: 3)  
 Section Type: rcjtcs

Constant Properties

-----  
 Knowledge Factor,  $\phi = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Jacket  
 New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 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  
 New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 450.00$   
 Max Width,  $W_{max} = 950.00$   
 Min Width,  $W_{min} = 450.00$   
 Eccentricity,  $E_{cc} = 250.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.22443  
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_o = 300.00$   
 No FRP Wrapping

#### Stepwise Properties

At local axis: 2  
 EDGE -A-  
 Shear Force,  $V_a = 1.3499588E-021$   
 EDGE -B-  
 Shear Force,  $V_b = -1.3499588E-021$   
 BOTH EDGES  
 Axial Force,  $F = -20792.022$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $A_{slt} = 0.00$   
 -Compression:  $A_{slc} = 6691.592$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $A_{sl,ten} = 1539.38$   
 -Compression:  $A_{sl,com} = 1539.38$   
 -Middle:  $A_{sl,mid} = 3612.832$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.22515134$   
 Member Controlled by Flexure ( $V_e/V_r < 1$ )  
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 361758.676$   
 with  
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 5.4264E+008$   
 $\mu_{u1+} = 5.4264E+008$ , 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  
 $\mu_{u1-} = 5.4264E+008$ , 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  
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 5.4264E+008$   
 $\mu_{u2+} = 5.4264E+008$ , 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  
 $\mu_{u2-} = 5.4264E+008$ , 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:

$$\mu = 4.1882964E-006$$

$$\mu_u = 5.4264E+008$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, c_o) = 0.01151713$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.01151713$$

$$\mu_{ue}(5.4c) = 0.04017143$$

$$\mu_{se}((5.4d), TBDY) = (\mu_{se1} * A_{ext} + \mu_{se2} * A_{int}) / A_{sec} = 0.53375773$$

$$\mu_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\mu_{se2} (> \mu_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\mu_{psh,min} * F_{ywe} = \text{Min}(\mu_{psh,x} * F_{ywe}, \mu_{psh,y} * F_{ywe}) = 2.48363$$

$$\mu_{psh,x} * F_{ywe} = \mu_{psh1} * F_{ywe1} + \mu_{psh2} * F_{ywe2} = 2.48363$$

$$\mu_{psh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$$

$$L_{stir1} (\text{Length of stirrups along Y}) = 2160.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$\mu_{psh2}((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$$

$$L_{stir2} (\text{Length of stirrups along Y}) = 1568.00$$

$$A_{stir2} (\text{stirrups area}) = 50.26548$$

$$\mu_{psh,y} * F_{ywe} = \mu_{psh1} * F_{ywe1} + \mu_{psh2} * F_{ywe2} = 2.97078$$

$$\mu_{psh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$$

$$L_{stir1} (\text{Length of stirrups along X}) = 2560.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$\mu_{psh2}((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$$

$$L_{stir2} (\text{Length of stirrups along X}) = 1968.00$$

$$A_{stir2} (\text{stirrups area}) = 50.26548$$

$$A_{sec} = 562500.00$$

$$s_1 = 100.00$$

$$s_2 = 250.00$$

```

fywe1 = 694.45
fywe2 = 694.45
fce = 33.00
From ((5A.5), TBDY), TBDY: cc = 0.00424426
c = confinement factor = 1.22443
y1 = 0.00092863
sh1 = 0.00297161
ft1 = 309.5449
fy1 = 257.9541
su1 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962
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 = 257.9541
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00092863
sh2 = 0.00297161
ft2 = 309.5449
fy2 = 257.9541
su2 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.02948185
2 = Asl,com/(b*d)*(fs2/fc) = 0.02948185
v = Asl,mid/(b*d)*(fsv/fc) = 0.06919209
and confined core properties:
b = 390.00
d = 877.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.03518117
2 = Asl,com/(b*d)*(fs2/fc) = 0.03518117
v = Asl,mid/(b*d)*(fsv/fc) = 0.08256805

```

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

--->  
v < vs,y2 - LHS eq.(4.5) is satisfied  
--->  
su (4.9) = 0.21774786  
Mu = MRc (4.14) = 5.4264E+008  
u = su (4.1) = 4.1882964E-006

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

Lap Length: lb/l<sub>d</sub> = 0.16198962  
lb = 300.00  
ld = 1851.971  
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
ld,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
= 1  
db = 16.66667  
Mean strength value of all re-bars: fy = 694.45  
Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 33.00, 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 = 1.37392  
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) = 250.00  
n = 30.00

Calculation of Mu1-

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

u = 4.1882964E-006  
Mu = 5.4264E+008

with full section properties:

b = 450.00  
d = 907.00  
d' = 43.00  
v = 0.0015437  
N = 20792.022  
fc = 33.00  
co (5A.5, TBDY) = 0.002  
Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01151713  
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY: cu = 0.01151713  
we (5.4c) = 0.04017143  
ase ((5.4d), TBDY) = (ase1\*Aext+ase2\*Aint)/Asec = 0.53375773  
ase1 = Max(((Aconf,max1-AnoConf1)/Aconf,max1)\*(Aconf,min1/Aconf,max1),0) = 0.53375773  
The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
Aconf,max1 = 464100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
Aconf,min1 = 395025.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.  
AnoConf1 = 173066.667 is the unconfined external core area which is equal to bi<sup>2</sup>/6 as defined at (A.2).

$$ase2 (>=ase1) = \text{Max}(((A_{conf,max2}-A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

$$psh2 \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

$A_{stir1}$  (stirrups area) = 78.53982

$$psh2 \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

$A_{stir2}$  (stirrups area) = 50.26548

$$A_{sec} = 562500.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 694.45$$

$$f_{ce} = 33.00$$

From ((5.A5), TBDY), TBDY:  $cc = 0.00424426$

$c$  = confinement factor = 1.22443

$$y1 = 0.00092863$$

$$sh1 = 0.00297161$$

$$ft1 = 309.5449$$

$$fy1 = 257.9541$$

$$su1 = 0.00297161$$

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

$$l_o/l_{ou,min} = l_b/l_d = 0.16198962$$

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

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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 257.9541$$

$$\text{with } Es1 = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$$

$$y2 = 0.00092863$$

$$sh2 = 0.00297161$$

$$ft2 = 309.5449$$

$$fy2 = 257.9541$$

$$su2 = 0.00297161$$

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

$$l_o/l_{ou,min} = l_b/l_{b,min} = 0.16198962$$

$$su2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

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  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs2 = (fs_{jacket} \cdot A_{sl,com,jacket} + fs_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 257.9541$   
 with  $Es2 = (Es_{jacket} \cdot A_{sl,com,jacket} + Es_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 200000.00$   
 $yv = 0.00092863$   
 $shv = 0.00297161$   
 $ftv = 309.5449$   
 $fyv = 257.9541$   
 $suv = 0.00297161$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/ld = 0.16198962$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $fsv = (fs_{jacket} \cdot A_{sl,mid,jacket} + fs_{mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 257.9541$   
 with  $Esv = (Es_{jacket} \cdot A_{sl,mid,jacket} + Es_{mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b \cdot d) \cdot (fs1/fc) = 0.02948185$   
 $2 = A_{sl,com} / (b \cdot d) \cdot (fs2/fc) = 0.02948185$   
 $v = A_{sl,mid} / (b \cdot d) \cdot (fsv/fc) = 0.06919209$   
 and confined core properties:  
 $b = 390.00$   
 $d = 877.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = A_{sl,ten} / (b \cdot d) \cdot (fs1/fc) = 0.03518117$   
 $2 = A_{sl,com} / (b \cdot d) \cdot (fs2/fc) = 0.03518117$   
 $v = A_{sl,mid} / (b \cdot d) \cdot (fsv/fc) = 0.08256805$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < vs,y2$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.21774786$   
 $Mu = MRc (4.14) = 5.4264E+008$   
 $u = su (4.1) = 4.1882964E-006$   
 -----  
 Calculation of ratio  $lb/ld$   
 -----  
 Lap Length:  $lb/ld = 0.16198962$   
 $lb = 300.00$   
 $ld = 1851.971$   
 Calculation of  $lb,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $ld,min$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $fy = 694.45$   
 Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $fc'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $Ktr = 1.37392$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$   
 $n = 30.00$   
 -----  
 -----  
 -----

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

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

$$\mu = 4.1882964E-006$$

$$\mu_{2+} = 5.4264E+008$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.022$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_{2+}: \mu_{2+}^* = \text{shear\_factor} * \text{Max}(\mu_{2+}, \alpha) = 0.01151713$$

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

$$\text{From (5.4b), TBDY: } \mu_{2+} = 0.01151713$$

$$\mu_{2+} (5.4c) = 0.04017143$$

$$\alpha_{se} ((5.4d), \text{TBDY}) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.53375773$$

$$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_{se2} (> \alpha_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 252164.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 111441.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 110709.333$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$$

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$$

$$p_{sh1} ((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$$

$$L_{stir1} (\text{Length of stirrups along Y}) = 2160.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$p_{sh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$$

$$L_{stir2} (\text{Length of stirrups along Y}) = 1568.00$$

$$A_{stir2} (\text{stirrups area}) = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$$

$$p_{sh1} ((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$$

$$L_{stir1} (\text{Length of stirrups along X}) = 2560.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$p_{sh2} ((5.4d), \text{TBDY}) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$$

$$L_{stir2} (\text{Length of stirrups along X}) = 1968.00$$

$$A_{stir2} (\text{stirrups area}) = 50.26548$$

$$A_{sec} = 562500.00$$

$$s_1 = 100.00$$

$$s_2 = 250.00$$

$$f_{ywe1} = 694.45$$

```

fywe2 = 694.45
fce = 33.00
From ((5A.5), TBDY), TBDY: cc = 0.00424426
c = confinement factor = 1.22443
y1 = 0.00092863
sh1 = 0.00297161
ft1 = 309.5449
fy1 = 257.9541
su1 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962
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 = 257.9541
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.00092863
sh2 = 0.00297161
ft2 = 309.5449
fy2 = 257.9541
su2 = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with shear_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 = 0.16198962
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 = 257.9541
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.00092863
shv = 0.00297161
ftv = 309.5449
fyv = 257.9541
suv = 0.00297161
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.16198962
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 = 257.9541
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.02948185
2 = Asl,com/(b*d)*(fs2/fc) = 0.02948185
v = Asl,mid/(b*d)*(fsv/fc) = 0.06919209
and confined core properties:
b = 390.00
d = 877.00
d' = 13.00
fcc (5A.2, TBDY) = 40.40604
cc (5A.5, TBDY) = 0.00424426
c = confinement factor = 1.22443
1 = Asl,ten/(b*d)*(fs1/fc) = 0.03518117
2 = Asl,com/(b*d)*(fs2/fc) = 0.03518117
v = Asl,mid/(b*d)*(fsv/fc) = 0.08256805
Case/Assumption: Unconfinedsd full section - Steel rupture

```

satisfies Eq. (4.3)

--->

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

--->

$\mu_u$  (4.9) = 0.21774786

$\mu_u = M_{Rc}$  (4.14) = 5.4264E+008

$u = \mu_u$  (4.1) = 4.1882964E-006

Calculation of ratio  $I_b/I_d$

Lap Length:  $I_b/I_d = 0.16198962$

$I_b = 300.00$

$I_d = 1851.971$

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

$I_d$ ,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)

= 1

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 694.45$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$

MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.37392$

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

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

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 30.00$

Calculation of  $\mu_u$ -

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

$u = 4.1882964E-006$

$\mu_u = 5.4264E+008$

with full section properties:

$b = 450.00$

$d = 907.00$

$d' = 43.00$

$v = 0.0015437$

$N = 20792.022$

$f'_c = 33.00$

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

Final value of  $\phi$ :  $\phi^* = \text{shear\_factor} \cdot \text{Max}(\phi_u, \phi_c) = 0.01151713$

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

From (5.4b), TBDY:  $\phi_u = 0.01151713$

we (5.4c) = 0.04017143

$\phi_{se}$  ((5.4d), TBDY) =  $(\phi_{se1} \cdot A_{ext} + \phi_{se2} \cdot A_{int}) / A_{sec} = 0.53375773$

$\phi_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.53375773$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 464100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 395025.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length

equal to half the clear spacing between external hoops.

$A_{noConf1} = 173066.667$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\phi_{se2} (\geq \phi_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) \cdot (A_{conf,min2} / A_{conf,max2}), 0) = 0.53375773$



The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 252164.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 111441.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 110709.333 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 2.48363

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 2.48363

psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00301593

Lstir1 (Length of stirrups along Y) = 2160.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) = Lstir2\*Astir2/(Asec\*s2) = 0.00056047

Lstir2 (Length of stirrups along Y) = 1568.00

Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 2.97078

psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00357443

Lstir1 (Length of stirrups along X) = 2560.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) = Lstir2\*Astir2/(Asec\*s2) = 0.00070345

Lstir2 (Length of stirrups along X) = 1968.00

Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00424426

c = confinement factor = 1.22443

y1 = 0.00092863

sh1 = 0.00297161

ft1 = 309.5449

fy1 = 257.9541

su1 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

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

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

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

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 257.9541

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

y2 = 0.00092863

sh2 = 0.00297161

ft2 = 309.5449

fy2 = 257.9541

su2 = 0.00297161

using (30) in Biskinis/Fardis (2013) multiplied with shear\_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 = 0.16198962

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  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 257.9541$   
 with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.00092863$   
 $sh_v = 0.00297161$   
 $ft_v = 309.5449$   
 $fy_v = 257.9541$   
 $suv = 0.00297161$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/ld = 0.16198962$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 257.9541$   
 with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.02948185$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.02948185$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.06919209$

and confined core properties:

$b = 390.00$   
 $d = 877.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 40.40604$   
 $cc (5A.5, TBDY) = 0.00424426$   
 $c = \text{confinement factor} = 1.22443$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.03518117$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.03518117$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.08256805$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.21774786$   
 $Mu = MRc (4.14) = 5.4264E+008$   
 $u = su (4.1) = 4.1882964E-006$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.16198962$   
 $lb = 300.00$   
 $ld = 1851.971$   
 Calculation of  $lb,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $ld,min$  from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (9.1.2, TS500 - No provision in ACI 318)  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $fy = 694.45$   
 Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $fc'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 1.37392$   
 $A_{tr} = Min(A_{tr_x}, A_{tr_y}) = 257.6106$   
 where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = Max(s_{external}, s_{internal}) = 250.00$   
 $n = 30.00$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.6067\text{E}+006$

Calculation of Shear Strength at edge 1,  $V_{r1} = 1.6067\text{E}+006$

$V_{r1} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{\text{Col}0}$

$V_{\text{Col}0} = 1.6067\text{E}+006$

$k_{nl} = 1$  (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:  $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.04067$

$\nu_u = 1.3499588\text{E}-021$

$d = 0.8 * h = 760.00$

$N_u = 20792.022$

$A_g = 427500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 1.1114\text{E}+006$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 977392.20$

$V_{s,j1} = 314161.779$  is calculated for section web jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 1.00$

$s/d = 0.27777778$

$V_{s,j2} = 663230.422$  is calculated for section flange jacket, with:

$d = 760.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 1.00$

$s/d = 0.13157895$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 134042.359$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 0.00$

$s/d = 1.25$

$V_{s,c2} = 134042.359$  is calculated for section flange core, with:

$d = 600.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 1.00$

$s/d = 0.41666667$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 0.00$

From (11-11), ACI 440:  $V_s + V_f \leq 1.3051\text{E}+006$

$bw = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.6067\text{E}+006$

$V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{\text{Col}0}$

$V_{\text{Col}0} = 1.6067\text{E}+006$

$k_{nl} = 1$  (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:  $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$   
 $\mu_u = 1.04067$   
 $V_u = 1.3499588E-021$   
 $d = 0.8 \cdot h = 760.00$   
 $N_u = 20792.022$   
 $A_g = 427500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 1.1114E+006$   
 where:  
 $V_{sjacket} = V_{sj1} + V_{sj2} = 977392.20$   
 $V_{sj1} = 314161.779$  is calculated for section web jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{sj1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.27777778$   
 $V_{sj2} = 663230.422$  is calculated for section flange jacket, with:  
 $d = 760.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{sj2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.13157895$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.25$   
 $V_{s,c2} = 134042.359$  is calculated for section flange core, with:  
 $d = 600.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.41666667$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 1.3051E+006$   
 $bw = 450.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
 At local axis: 2  
 -----

-----  
 Start Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1  
 At local axis: 3  
 Integration Section: (b)  
 Section Type: rcjtcs

Constant Properties

-----  
 Knowledge Factor,  $\phi = 1.00$   
 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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 450.00$   
 Max Width,  $W_{max} = 950.00$   
 Min Width,  $W_{min} = 450.00$   
 Eccentricity,  $Ecc = 250.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_b = 300.00$   
 No FRP Wrapping

#### Stepwise Properties

Bending Moment,  $M = 209031.971$   
 Shear Force,  $V_2 = 9644.583$   
 Shear Force,  $V_3 = -108.1943$   
 Axial Force,  $F = -21706.813$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{st} = 0.00$   
   -Compression:  $A_{sc} = 6691.592$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{st,ten} = 1539.38$   
   -Compression:  $A_{st,com} = 1539.38$   
   -Middle:  $A_{st,mid} = 3612.832$   
 Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{st,ten,jacket} = 1231.504$   
   -Compression:  $A_{st,com,jacket} = 1231.504$   
   -Middle:  $A_{st,mid,jacket} = 2689.203$   
 Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{st,ten,core} = 307.8761$   
   -Compression:  $A_{st,com,core} = 307.8761$   
   -Middle:  $A_{st,mid,core} = 923.6282$   
 Mean Diameter of Tension Reinforcement,  $Db_L = 16.57143$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = 1.0^*$   $u = 0.02760399$   
 $u = y + p = 0.02760399$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00018669$  ((4.29), Biskinis Phd))  
 $M_y = 5.2064E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) =  $300.00$   
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.7887E+014$   
 $factor = 0.30$   
 $A_g = 562500.00$   
 Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 33.00$   
 $N = 21706.813$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 9.2958E+014$

Calculation of Yielding Moment  $M_y$

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

```

y = Min( y_ten, y_com)
y_ten = 1.7803962E-006
with ((10.1), ASCE 41-17) fy = Min(fy, 1.25*fy*(lb/d)^ 2/3) = 239.4634
d = 907.00
y = 0.25854434
A = 0.01661703
B = 0.0088082
with pt = 0.0037716
pc = 0.0037716
pv = 0.00885172
N = 21706.813
b = 450.00
" = 0.04740904
y_comp = 9.4777698E-006
with fc = 33.00
Ec = 26999.444
y = 0.25592822
A = 0.01627407
B = 0.0085861
with Es = 200000.00

```

#### Calculation of ratio lb/d

```

Lap Length: ld/d,min = 0.20248702
lb = 300.00
ld = 1481.576
Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
ld,min from (25.4.3.2) is multiplied 2 times to account for smooth re-bars (10.3.5, ASCE 41-17)
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 555.56
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, 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 = 1.37392
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) = 250.00
n = 30.00

```

#### - Calculation of p -

```

From table 10-8: p = 0.0274173
with:
- Columns controlled by inadequate development or splicing along the clear height because lb/d < 1
shear control ratio VyE/VColOE = 0.22515134
d = d_external = 907.00
s = s_external = 0.00
- t = s1 + s2 + 2*tf/bw*(ffe/fs) = 0.00427788
jacket: s1 = Av1*Lstir1/(s1*Ag) = 0.00357443
Av1 = 78.53982, is the area of every stirrup parallel to loading (shear) direction
Lstir1 = 2560.00, is the total Length of all stirrups parallel to loading (shear) direction
s1 = 100.00
core: s2 = Av2*Lstir2/(s2*Ag) = 0.00070345
Av2 = 50.26548, is the area of every stirrup parallel to loading (shear) direction
Lstir2 = 1968.00, is the total Length of all stirrups parallel to loading (shear) direction
s2 = 250.00
The term 2*tf/bw*(ffe/fs) is implemented to account for FRP contribution
where f = 2*tf/bw is FRP ratio (EC8 - 3, A.4.4.3(6)) and ffe/fs normalises f to steel strength
All these variables have already been given in Shear control ratio calculation.

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For the normalisation  $f_s$  of jacket is used.

$$N_{UD} = 21706.813$$

$$A_g = 562500.00$$

$$f_{cE} = (f_{c\_jacket} \cdot Area\_jacket + f_{c\_core} \cdot Area\_core) / section\_area = 33.00$$

$$f_{yE} = (f_{y\_ext\_Long\_Reinf} \cdot Area\_ext\_Long\_Reinf + f_{y\_int\_Long\_Reinf} \cdot Area\_int\_Long\_Reinf) / Area\_Tot\_Long\_Rein = 555.56$$

$$f_{yE} = (f_{y\_ext\_Trans\_Reinf} \cdot s_1 + f_{y\_int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 555.56$$

$$\rho_l = Area\_Tot\_Long\_Rein / (b \cdot d) = 0.01639493$$

$$b = 450.00$$

$$d = 907.00$$

$$f_{cE} = 33.00$$

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End Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1

At local axis: 3

Integration Section: (b)

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