

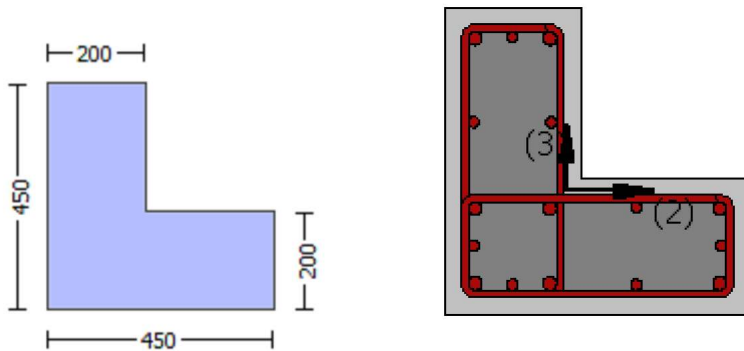
# Detailed Member Calculations

**Units: N&mm**

**Regulation: ASCE 41-17**

## Calculation No. 1

column C1, Floor 1  
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)  
Analysis: Uniform +X  
Check: Shear capacity  $V_{Rd}$   
Edge: Start  
Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1  
At local axis: 2  
Integration Section: (a)  
Section Type: rdcs

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:  
Existing material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 12.00$   
Existing material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$   
Concrete Elasticity,  $E_c = 19940.411$

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).  
 Existing material: Concrete Strength,  $f_c = f_{cm} = 18.00$   
 Existing material: Steel Strength,  $f_s = f_{sm} = 444.44$   
 #####  
 Max Height,  $H_{max} = 450.00$   
 Min Height,  $H_{min} = 200.00$   
 Max Width,  $W_{max} = 450.00$   
 Min Width,  $W_{min} = 200.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_o/l_{ou,min} = l_b/l_d \geq 1$ )  
 No FRP Wrapping

#### Stepwise Properties

EDGE -A-  
 Bending Moment,  $M_a = -1.8641E+008$   
 Shear Force,  $V_a = 33259.52$   
 EDGE -B-  
 Bending Moment,  $M_b = 1.1506E+008$   
 Shear Force,  $V_b = -33259.52$   
 BOTH EDGES  
 Axial Force,  $F = -1.4054E+006$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $A_{st} = 1545.664$   
 -Compression:  $A_{sc} = 2576.106$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $A_{st,ten} = 1746.726$   
 -Compression:  $A_{st,com} = 829.3805$   
 -Middle:  $A_{st,mid} = 1545.664$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = V_n = 186268.73$   
 $V_n ((10.3), ASCE 41-17) = k_n l * V_{CoI0} = 186268.73$   
 $V_{CoI} = 206188.01$   
 $k_n l = 0.90339264$   
 $displacement\_ductility\_demand = 3.2881$

NOTE: In expression (10-3) ' $V_s$ ' is replaced by ' $V_{s+ f} * V_f$ '  
 where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$\gamma = 1$  (normal-weight concrete)  
 $f'_c = 12.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 1.8641E+008$   
 $V_u = 33259.52$   
 $d = 0.8 * h = 360.00$   
 $N_u = 1.4054E+006$   
 $A_g = 90000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 107711.748$   
 where:  
 $V_{s1} = 0.00$  is calculated for section web, with:  
 $d = 160.00$   
 $A_v = 157079.633$

$f_y = 400.00$   
 $s = 210.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.00$   
 $s/d = 1.3125$   
 $V_{s2} = 107711.748$  is calculated for section flange, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 210.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.58333333$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From  $(11-11)$ , ACI 440:  $V_s + V_f \leq 165687.55$   
 $bw = 200.00$

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

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

From analysis, chord rotation  $\theta = 0.04061215$   
 $y = (M_y * L_s / 3) / E_{eff} = 0.01235126 ((4.29), Biskinis Phd)$   
 $M_y = 2.0187E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) =  $5604.816$   
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 3.0536E+013$   
 $factor = 0.70$   
 $A_g = 140000.00$   
 $f_c' = 18.00$   
 $N = 1.4054E+006$   
 $E_c * I_g = 4.3623E+013$

Calculation of Yielding Moment  $M_y$

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

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 1.3705819E-005$   
 with  $f_y = 444.44$   
 $d = 407.00$   
 $y = 0.60163265$   
 $A = 0.08948478$   
 $B = 0.07188114$   
 with  $p_t = 0.02145854$   
 $p_c = 0.01018895$   
 $p_v = 0.0189885$   
 $N = 1.4054E+006$   
 $b = 200.00$   
 $" = 0.10565111$   
 $y_{comp} = 4.7559098E-006$   
 with  $f_c = 18.00$   
 $E_c = 19940.411$   
 $y = 0.8394269$   
 $A = -0.00249523$   
 $B = 0.03303234$   
 with  $E_s = 200000.00$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1  
 At local axis: 2

## Calculation No. 2

column C1, Floor 1

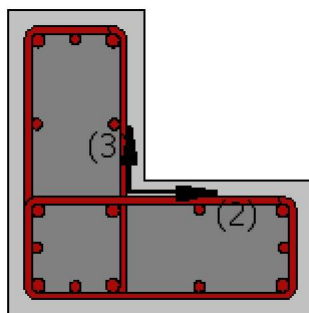
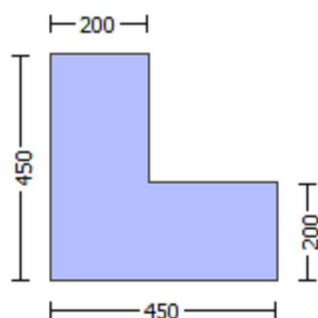
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\mu$  )

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rdcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 18.00$

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

Concrete Elasticity,  $E_c = 19940.411$

Steel Elasticity,  $E_s = 200000.00$

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Note: Especially for the calculation of moment strengths,

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

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

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Max Height,  $H_{max} = 450.00$

Min Height,  $H_{min} = 200.00$

Max Width,  $W_{max} = 450.00$

Min Width,  $W_{min} = 200.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length,  $L = 3000.00$

Secondary Member  
Smooth Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Adequate Lap Length ( $l_o/l_{ou}, \min > 1$ )  
No FRP Wrapping

#### Stepwise Properties

At local axis: 3  
EDGE -A-  
Shear Force,  $V_a = -8.8389216E-005$   
EDGE -B-  
Shear Force,  $V_b = 8.8389216E-005$   
BOTH EDGES  
Axial Force,  $F = -1.4060E+006$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 829.3805$   
-Compression:  $As_c = 3091.327$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten} = 829.3805$   
-Compression:  $As_{c,com} = 1746.726$   
-Middle:  $As_{mid} = 1545.664$

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.14637$   
Member Controlled by Shear ( $V_e/V_r > 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 263541.358$   
with  
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 3.9531E+008$   
 $\mu_{u1+} = 3.9531E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination  
 $\mu_{u1-} = 2.8814E+008$ , 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  
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 3.9531E+008$   
 $\mu_{u2+} = 3.9531E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination  
 $\mu_{u2-} = 2.8814E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

#### Calculation of $\mu_{u1+}$

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\mu_u = 1.0666733E-005$   
 $\mu_u = 3.9531E+008$

with full section properties:

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.42649604$   
 $N = 1.4060E+006$   
 $f_c = 18.00$   
 $\phi_c (5A.5, TBDY) = 0.002$   
Final value of  $\phi_{cu}$ :  $\phi_{cu} = \text{shear\_factor} * \max(\phi_{cu}, \phi_c) = 0.00548378$   
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY:  $\phi_{cu} = 0.00548378$   
 $\phi_{we} (5.4c) = 0.00245962$   
 $\phi_{ase} = \max(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.09380979$   
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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00283171$

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

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00283171$

$L_{stir}$  (Length of stirrups along Y) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00283171$

$L_{stir}$  (Length of stirrups along X) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$s = 210.00$

$f_{ywe} = 555.55$

$f_{ce} = 18.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.002$

$c = \text{confinement factor} = 1.00$

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

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

$lo/lou,min = lb/ld = 1.00$

$su_1 = 0.4 \cdot esu1\_nominal \text{ ((5.5), TBDY)} = 0.032$

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

For calculation of  $esu1\_nominal$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

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

with  $fs_1 = fs = 555.55$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

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

$lo/lou,min = lb/lb,min = 1.00$

$su_2 = 0.4 \cdot esu2\_nominal \text{ ((5.5), TBDY)} = 0.032$

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

For calculation of  $esu2\_nominal$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.

$y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_2 = fs = 555.55$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$su_v = 0.032$

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

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and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lo,min = lb/ld = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.4973444
MRo (4.18) = 3.9531E+008
---->
u = cu (4.2) = 1.0666733E-005
Mu = MRo
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Calculation of ratio  $l_b/d$

Adequate Lap Length:  $l_b/d \geq 1$

Calculation of  $\mu_1$ -

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

$$\mu = 1.6699237E-005$$

$$\mu_u = 2.8814E+008$$

with full section properties:

$$b = 200.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$\nu = 0.95961609$$

$$N = 1.4060E+006$$

$$f_c = 18.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \mu_c) = 0.00548378$$

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

$$\text{From (5.4b), TB DY: } \mu_u = 0.00548378$$

$$\mu_c (5.4c) = 0.00245962$$

$$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.00283171$$

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

$$\mu_{psh,x} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$\mu_{psh,y} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along X}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 18.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \mu_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

$$l_o/l_{ou,min} = l_b/d = 1.00$$



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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 = 555.55
with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
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 = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.66229413
2 = Asl,com/(b*d)*(fs2/fc) = 0.31447059
v = Asl,mid/(b*d)*(fsv/fc) = 0.58605883
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < s,y1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is not satisfied
--->

```

$c_u(4.11) = 0.80684338$   
 $M_{Rc}(4.18) = 2.8814E+008$   
 --->  
 New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover  
 In expressions below, the following modifications have been made  
 - b, d, d' replaced by geometric parameters of the core:  $b_o$ ,  $d_o$ ,  $d'_o$   
 -  $N$ ,  $1$ ,  $2$ ,  $v$  normalised to  $b_o*d_o$ , instead of  $b*d$   
 - - parameters of confined concrete,  $f_{cc}$ ,  $\epsilon_{cc}$ , used in lieu of  $f_c$ ,  $\epsilon_{cu}$

Subcase: Rupture of tension steel

$v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied

$v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied

Subcase rejected

New Subcase: Failure of compression zone

$v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied

$v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied

$*c_u(4.11) = 0.98280667$

$M_{Ro}(4.18) = 1.3661E+008$

$M_{Ro} < 0.8*M_{Rc}$

$u = c_u$  (unconfined full section) =  $1.6699237E-005$

$\mu = M_{Rc}$

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of  $\mu_{2+}$

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

$u = 1.0666733E-005$

$\mu = 3.9531E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.42649604$

$N = 1.4060E+006$

$f_c = 18.00$

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

Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, \epsilon_{cc}) = 0.00548378$

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

From (5.4b), TB DY:  $c_u = 0.00548378$

$\epsilon_{we}(5.4c) = 0.00245962$

$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.09380979$

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.

$A_{\text{conf,max}} = 89600.00$  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 perimeter hoops.

$A_{\text{conf,min}} = 21600.00$  is the confined core area at midway between the levels of hoops and

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

equal to half the clear spacing between hoops.

AnoConf = 54733.333 is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} = \min(psh_x, psh_y) = 0.00283171$

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

$psh_x \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00283171$

$L_{stir}$  (Length of stirrups along Y) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$psh_y \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00283171$

$L_{stir}$  (Length of stirrups along X) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$s = 210.00$

$f_{ywe} = 555.55$

$f_{ce} = 18.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.002$

$c$  = confinement factor = 1.00

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

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

$lo/lo_{min} = lb/ld = 1.00$

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

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

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

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

with  $fs_1 = fs = 555.55$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

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

$lo/lo_{min} = lb/lb_{min} = 1.00$

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

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

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

$y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $\min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_2 = fs = 555.55$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$suv = 0.032$

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

$lo/lo_{min} = lb/ld = 1.00$

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

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

considering characteristic value  $fsy_v = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $fsy_v = fsv/1.2$ , from table 5.1, TBDY.

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

with  $f_{sv} = f_s = 555.55$

with  $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.13976471$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.29435295$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.26047059$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$f_{cc} \text{ (5A.2, TBDY)} = 18.00$

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

$c = \text{confinement factor} = 1.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.17409989$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.36666491$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.32445888$

Case/Assumption: Unconfined full section - Steel rupture

' does not satisfy Eq. (4.3)

----

$v < v_{s,c}$  - RHS eq.(4.5) is not satisfied

----

Case/Assumption Rejected.

----

New Case/Assumption: Unconfined full section - Spalling of concrete cover

' satisfies Eq. (4.4)

----

$v < s_{y1}$  - LHS eq.(4.7) is not satisfied

----

$v < v_{c,y1}$  - RHS eq.(4.6) is satisfied

----

$\epsilon_{cu} \text{ (4.10)} = 0.40653976$

$M_{Rc} \text{ (4.17)} = 4.7962E+008$

----

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

-  $b, d, d'$  replaced by geometric parameters of the core:  $b_o, d_o, d'_o$

-  $N, 1, 2, v$  normalised to  $b_o \cdot d_o$ , instead of  $b \cdot d$

-  $f_{cc}, cc$  parameters of confined concrete,  $f_{cc}, cc$ , used in lieu of  $f_c, \epsilon_{cu}$

----

Subcase: Rupture of tension steel

----

$v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied

----

$v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied

----

Subcase rejected

----

New Subcase: Failure of compression zone

----

$v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied

----

$v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied

----

$\epsilon^*_{cu} \text{ (4.11)} = 0.4973444$

$M_{Ro} \text{ (4.18)} = 3.9531E+008$

----

$u = \epsilon_{cu} \text{ (4.2)} = 1.0666733E-005$

$\mu = M_{Ro}$

-----

Calculation of ratio  $l_b/d$

-----

Adequate Lap Length:  $l_b/d \geq 1$

-----

-----

-----

Calculation of  $\mu_{u2}$ -

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

$$\phi_u = 1.6699237E-005$$

$$\mu = 2.8814E+008$$

with full section properties:

$$b = 200.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$\nu = 0.95961609$$

$$N = 1.4060E+006$$

$$f_c = 18.00$$

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

$$\text{Final value of } \phi_{cu}: \phi_{cu}^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.00548378$$

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

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.00548378$$

$$\phi_{we}(5.4c) = 0.00245962$$

$$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\phi_{psh,min} = \text{Min}(\phi_{psh,x}, \phi_{psh,y}) = 0.00283171$$

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

$$\phi_{psh,x}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1060.00$$

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

$$A_{sec} \text{ (section area)} = 140000.00$$

$$\phi_{psh,y}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1060.00$$

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

$$A_{sec} \text{ (section area)} = 140000.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 18.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_{cc} = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$\phi_{y1} = 0.00231479$$

$$\phi_{sh1} = 0.008$$

$$f_{t1} = 666.66$$

$$f_{y1} = 555.55$$

$$\phi_{su1} = 0.032$$

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

$$\phi_{lo/\phi_{ou,min}} = \phi_b / \phi_d = 1.00$$

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

$$\text{From table 5A.1, TBDY: } \phi_{su1\_nominal} = 0.08,$$

For calculation of  $\phi_{su1\_nominal}$  and  $\phi_{y1}$ ,  $\phi_{sh1}$ ,  $f_{t1}$ ,  $f_{y1}$ , it is considered characteristic value  $f_{sy1} = f_{s1} / 1.2$ , from table 5.1, TBDY.

$\phi_{y1}$ ,  $\phi_{sh1}$ ,  $f_{t1}$ ,  $f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (\phi_b / \phi_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{s1} = f_s = 555.55$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$\phi_{y2} = 0.00231479$$

```

sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
    using (30) in Biskinis/Fardis (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 = 1.00
    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 = 555.55
    with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (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 = 1.00
    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 = 555.55
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.66229413
2 = Asl,com/(b*d)*(fs2/fc) = 0.31447059
v = Asl,mid/(b*d)*(fsv/fc) = 0.58605883
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is not satisfied
--->
cu (4.11) = 0.80684338
MRc (4.18) = 2.8814E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu

```

```

---->
Subcase: Rupture of tension steel
---->
 $v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied
---->
 $v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
 $v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied
---->
 $v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied
---->
 $*c_u(4.11) = 0.98280667$ 
 $M_{Ro}(4.18) = 1.3661E+008$ 
 $M_{Ro} < 0.8 * M_{Rc}$ 
---->
 $u = c_u$  (unconfined full section) = 1.6699237E-005
 $\mu = M_{Rc}$ 
-----

Calculation of ratio  $l_b/d$ 
-----
Adequate Lap Length:  $l_b/d \geq 1$ 
-----
-----
-----
Calculation of Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 229892.529$ 
-----
Calculation of Shear Strength at edge 1,  $V_{r1} = 229892.529$ 
 $V_{r1} = V_{Col}((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$ 
 $V_{Col0} = 229892.529$ 
 $k_{nl} = 1$  (zero step-static loading)
-----
NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).
-----
= 1 (normal-weight concrete)
 $f'_c = 18.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$ 
 $\mu = 1.2877E+008$ 
 $V_u = 8.8389216E-005$ 
 $d = 0.8 * h = 360.00$ 
 $N_u = 1.4060E+006$ 
 $A_g = 90000.00$ 
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$ 
where:
 $V_{s1} = 119678.523$  is calculated for section web, with:
 $d = 360.00$ 
 $A_v = 157079.633$ 
 $f_y = 444.44$ 
 $s = 210.00$ 
 $V_{s1}$  is multiplied by  $Col1 = 1.00$ 
 $s/d = 0.58333333$ 
 $V_{s2} = 0.00$  is calculated for section flange, with:
 $d = 160.00$ 
 $A_v = 157079.633$ 
 $f_y = 444.44$ 
 $s = 210.00$ 
 $V_{s2}$  is multiplied by  $Col2 = 0.00$ 
 $s/d = 1.3125$ 
 $V_f((11-3)-(11.4), ACI 440) = 0.00$ 
From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$ 
 $b_w = 200.00$ 

```

Calculation of Shear Strength at edge 2,  $V_{r2} = 229892.529$

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

$V_{Col0} = 229892.529$

$knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s$ ' is replaced by ' $V_{s+} + f * V_f$ '  
where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)

$f_c' = 18.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$M_u = 1.1237E+008$

$V_u = 8.8389216E-005$

$d = 0.8 * h = 360.00$

$N_u = 1.4060E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$

where:

$V_{s1} = 119678.523$  is calculated for section web, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$s/d = 0.58333333$

$V_{s2} = 0.00$  is calculated for section flange, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

$V_{s2}$  is multiplied by  $Col2 = 0.00$

$s/d = 1.3125$

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

From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$

$bw = 200.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rdlcs

Constant Properties

Knowledge Factor,  $= 1.00$

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

Consequently:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 18.00$

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

Concrete Elasticity,  $E_c = 19940.411$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height,  $H_{max} = 450.00$

Min Height,  $H_{min} = 200.00$

Max Width,  $W_{max} = 450.00$



Min Width,  $W_{min} = 200.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.00  
Element Length,  $L = 3000.00$   
Secondary Member  
Smooth Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Adequate Lap Length ( $l_o/l_{ou,min} > 1$ )  
No FRP Wrapping

#### Stepwise Properties

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = 3.7569140E-005$   
EDGE -B-  
Shear Force,  $V_b = -3.7569140E-005$   
BOTH EDGES  
Axial Force,  $F = -1.4060E+006$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 829.3805$   
-Compression:  $As_c = 3091.327$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten} = 1746.726$   
-Compression:  $As_{c,com} = 829.3805$   
-Middle:  $As_{mid} = 1545.664$

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.14637$   
Member Controlled by Shear ( $V_e/V_r > 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 263541.358$   
with  
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 3.9531E+008$   
 $\mu_{u1+} = 2.8814E+008$ , 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  
 $\mu_{u1-} = 3.9531E+008$ , 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  
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 3.9531E+008$   
 $\mu_{u2+} = 2.8814E+008$ , 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  
 $\mu_{u2-} = 3.9531E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

#### Calculation of $\mu_{u1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\phi_u = 1.6699237E-005$   
 $\mu_u = 2.8814E+008$

with full section properties:

$b = 200.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.95961609$   
 $N = 1.4060E+006$   
 $f_c = 18.00$   
 $\phi_{co} (5A.5, \text{TDY}) = 0.002$   
Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_{co}) = 0.00548378$   
The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $c_u = 0.00548378$

$w_e$  (5.4c) = 0.00245962

$a_s = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.09380979$

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.

$A_{\text{conf,max}}$  = 89600.00 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 perimeter hoops.

$A_{\text{conf,min}}$  = 21600.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}}$  = 54733.333 is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00283171$

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

$p_{sh,x}$  ((5.4d), TBDY) =  $L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00283171$

$L_{\text{stir}}$  (Length of stirrups along Y) = 1060.00

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

$A_{\text{sec}}$  (section area) = 140000.00

$p_{sh,y}$  ((5.4d), TBDY) =  $L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00283171$

$L_{\text{stir}}$  (Length of stirrups along X) = 1060.00

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

$A_{\text{sec}}$  (section area) = 140000.00

$s = 210.00$

$f_{ywe} = 555.55$

$f_{ce} = 18.00$

From ((5.A5), TBDY), TBDY:  $c_c = 0.002$

$c$  = confinement factor = 1.00

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

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

$l_o/l_{ou,min} = l_b/l_d = 1.00$

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

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

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

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

with  $fs_1 = fs = 555.55$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

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

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$

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

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

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

$y_2$ ,  $sh_2$ ,  $ft_2$ ,  $fy_2$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_2 = fs = 555.55$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

```

ftv = 666.66
fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (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 = 1.00
    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 = 555.55
    with Esv = Es = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.66229413
    2 = Asl,com/(b*d)*(fs2/fc) = 0.31447059
    v = Asl,mid/(b*d)*(fsv/fc) = 0.58605883
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
    2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
    v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.80684338
MRc (4.18) = 2.8814E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.98280667
MRo (4.18) = 1.3661E+008

```

$$M_{Ro} < 0.8 \cdot M_{Rc}$$

---->

$$u = c_u \text{ (unconfined full section)} = 1.6699237E-005$$

$$M_u = M_{Rc}$$

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of  $M_{u1}$ -

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

$$u = 1.0666733E-005$$

$$M_u = 3.9531E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.42649604$$

$$N = 1.4060E+006$$

$$f_c = 18.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} \cdot \text{Max}(c_u, c_c) = 0.00548378$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.00548378$$

$$w_e \text{ (5.4c)} = 0.00245962$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00283171$$

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

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00283171$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1060.00$$

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

$$A_{sec} \text{ (section area)} = 140000.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00283171$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1060.00$$

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

$$A_{sec} \text{ (section area)} = 140000.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 18.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$f_{t1} = 666.66$$

$$f_{y1} = 555.55$$

```

su1 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
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 = 555.55
with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
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 = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)

```

```

---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu

```

```

---->
Subcase: Rupture of tension steel

```

```

---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied

```

```

---->
v* < v*s,c - LHS eq.(4.5) is not satisfied

```

```

---->
Subcase rejected

```

```

---->
New Subcase: Failure of compression zone

```

```

---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied

```

```

---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied

```

```

---->
*cu (4.11) = 0.4973444

```

```

MRO (4.18) = 3.9531E+008

```

```

---->
u = cu (4.2) = 1.0666733E-005

```

```

Mu = MRO

```

```

-----
Calculation of ratio lb/d

```

```

-----
Adequate Lap Length: lb/d >= 1

```

```

-----
Calculation of Mu2+

```

```

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

```

```

u = 1.6699237E-005

```

```

Mu = 2.8814E+008

```

```

-----
with full section properties:

```

```

b = 200.00

```

```

d = 407.00

```

```

d' = 43.00

```

```

v = 0.95961609

```

```

N = 1.4060E+006

```

```

fc = 18.00

```

```

co (5A.5, TBDY) = 0.002

```

```

Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.00548378

```

```

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

```

```

From (5.4b), TBDY: cu = 0.00548378

```

```

we (5.4c) = 0.00245962

```

```

ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.09380979

```

```

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,max = 89600.00 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 perimeter hoops.  
Aconf,min = 21600.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 54733.333 is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00283171

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

psh,x ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00283171

Lstir (Length of stirrups along Y) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00283171

Lstir (Length of stirrups along X) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

s = 210.00

fywe = 555.55

fce = 18.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

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

lo/lou,min = lb/lb,min = 1.00

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 = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = fs = 555.55$   
with  $Esv = Es = 200000.00$   
 $1 = Asl,ten/(b \cdot d) \cdot (fs1/fc) = 0.66229413$   
 $2 = Asl,com/(b \cdot d) \cdot (fs2/fc) = 0.31447059$   
 $v = Asl,mid/(b \cdot d) \cdot (fsv/fc) = 0.58605883$   
and confined core properties:  
 $b = 140.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 18.00$   
 $cc (5A.5, TBDY) = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = Asl,ten/(b \cdot d) \cdot (fs1/fc) = 1.02142$   
 $2 = Asl,com/(b \cdot d) \cdot (fs2/fc) = 0.48499254$   
 $v = Asl,mid/(b \cdot d) \cdot (fsv/fc) = 0.90384974$   
Case/Assumption: Unconfined full section - Steel rupture  
' does not satisfy Eq. (4.3)  
---->  
 $v < vs,c$  - RHS eq.(4.5) is not satisfied  
---->  
Case/Assumption Rejected.  
---->  
New Case/Assumption: Unconfined full section - Spalling of concrete cover  
' satisfies Eq. (4.4)  
---->  
 $v < sy1$  - LHS eq.(4.7) is not satisfied  
---->  
 $v < vc,y1$  - RHS eq.(4.6) is not satisfied  
---->  
 $cu (4.11) = 0.80684338$   
 $MRC (4.18) = 2.8814E+008$   
---->  
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover  
In expressions below, the following modifications have been made  
-  $b, d, d'$  replaced by geometric parameters of the core:  $bo, do, d'o$   
-  $N, 1, 2, v$  normalised to  $bo \cdot do$ , instead of  $b \cdot d$   
-  $parameters of confined concrete, fcc, cc, used in lieu of fc, ecu$   
---->  
Subcase: Rupture of tension steel  
---->  
 $v^* < vs,y2$  - LHS eq.(4.5) is not satisfied  
---->  
 $v^* < vs,c$  - LHS eq.(4.5) is not satisfied  
---->  
Subcase rejected  
---->  
New Subcase: Failure of compression zone  
---->  
 $v^* < vc,y2$  - LHS eq.(4.6) is not satisfied  
---->  
 $v^* < vc,y1$  - RHS eq.(4.6) is not satisfied  
---->  
 $*cu (4.11) = 0.98280667$   
 $MRO (4.18) = 1.3661E+008$   
 $MRO < 0.8 \cdot MRC$   
---->  
 $u = cu \text{ (unconfined full section)} = 1.6699237E-005$   
 $Mu = MRC$

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



Adequate Lap Length:  $l_b/d \geq 1$

Calculation of  $\mu_2$ -

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

$$\mu = 1.0666733E-005$$

$$\mu_u = 3.9531E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.42649604$$

$$N = 1.4060E+006$$

$$f_c = 18.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, c_o) = 0.00548378$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.00548378$$

$$\mu_{ue} \text{ (5.4c)} = 0.00245962$$

$$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.00283171$$

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

$$\mu_{psh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1060.00$$

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

$$A_{sec} \text{ (section area)} = 140000.00$$

$$\mu_{psh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1060.00$$

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

$$A_{sec} \text{ (section area)} = 140000.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 18.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

$$l_o/l_{ou,min} = l_b/d = 1.00$$

$$su_1 = 0.4 * esu_1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_1_{nominal} = 0.08,$$

For calculation of  $esu_1_{nominal}$  and  $y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , it is considered

characteristic value  $f_{sy1} = f_{s1}/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $f_{s1} = f_s = 555.55$   
 with  $E_{s1} = E_s = 200000.00$   
 $y2 = 0.00231479$   
 $sh2 = 0.008$   
 $ft2 = 666.66$   
 $fy2 = 555.55$   
 $su2 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_{b,min} = 1.00$   
 $su2 = 0.4 \cdot esu2\_nominal \cdot ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
 For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $f_{s2} = f_s = 555.55$   
 with  $E_{s2} = E_s = 200000.00$   
 $yv = 0.00231479$   
 $shv = 0.008$   
 $ftv = 666.66$   
 $fyv = 555.55$   
 $suv = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 1.00$   
 $suv = 0.4 \cdot esuv\_nominal \cdot ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $f_{sv} = f_s = 555.55$   
 with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.13976471$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.29435295$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.26047059$   
 and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 18.00$   
 $cc (5A.5, TBDY) = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.17409989$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.36666491$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.32445888$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' does not satisfy Eq. (4.3)  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is not satisfied  
 --->  
 Case/Assumption Rejected.  
 --->  
 New Case/Assumption: Unconfined full section - Spalling of concrete cover  
 ' satisfies Eq. (4.4)  
 --->  
 $v < s_{y1}$  - LHS eq.(4.7) is not satisfied  
 --->  
 $v < v_{c,y1}$  - RHS eq.(4.6) is satisfied  
 --->  
 $cu (4.10) = 0.40653976$   
 $MRC (4.17) = 4.7962E+008$   
 --->

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N,  $\epsilon_1$ ,  $\epsilon_2$ ,  $\nu$  normalised to bo\*do, instead of b\*d
- parameters of confined concrete, fcc,  $\epsilon_{cc}$ , used in lieu of fc,  $\epsilon_{cu}$

--->

Subcase: Rupture of tension steel

--->

$\nu^* < \nu^* s_y$  - LHS eq.(4.5) is not satisfied

--->

$\nu^* < \nu^* s_c$  - LHS eq.(4.5) is not satisfied

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

$\nu^* < \nu^* c_y$  - LHS eq.(4.6) is not satisfied

--->

$\nu^* < \nu^* c_{y1}$  - RHS eq.(4.6) is not satisfied

--->

$\epsilon_{cu} (4.11) = 0.4973444$

$M_{Ro} (4.18) = 3.9531E+008$

--->

$u = \epsilon_{cu} (4.2) = 1.0666733E-005$

$\mu_u = M_{Ro}$

-----  
Calculation of ratio lb/d

Adequate Lap Length: lb/d  $\geq 1$

-----  
Calculation of Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 229892.529$

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 229892.529$

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

$V_{Col0} = 229892.529$

$k_n l = 1$  (zero step-static loading)

-----  
NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+  $f^* V_f$ '  
where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

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

$f_c' = 18.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.2440E+008$

$V_u = 3.7569140E-005$

$d = 0.8^* h = 360.00$

$N_u = 1.4060E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$

where:

$V_{s1} = 0.00$  is calculated for section web, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

$V_{s1}$  is multiplied by  $Col1 = 0.00$

$s/d = 1.3125$

$V_{s2} = 119678.523$  is calculated for section flange, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

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

s/d = 0.58333333  
Vf ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440: Vs + Vf <= 202924.977  
bw = 200.00

-----  
Calculation of Shear Strength at edge 2, Vr2 = 229892.529  
Vr2 = VCol ((10.3), ASCE 41-17) = knl\*VCol0  
VCol0 = 229892.529  
knl = 1 (zero step-static loading)

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

-----  
= 1 (normal-weight concrete)  
fc' = 18.00, but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
M/Vd = 4.00  
Mu = 1.0841E+008  
Vu = 3.7569140E-005  
d = 0.8\*h = 360.00  
Nu = 1.4060E+006  
Ag = 90000.00  
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 119678.523  
where:  
Vs1 = 0.00 is calculated for section web, with:  
d = 160.00  
Av = 157079.633  
fy = 444.44  
s = 210.00  
Vs1 is multiplied by Col1 = 0.00  
s/d = 1.3125  
Vs2 = 119678.523 is calculated for section flange, with:  
d = 360.00  
Av = 157079.633  
fy = 444.44  
s = 210.00  
Vs2 is multiplied by Col2 = 1.00  
s/d = 0.58333333  
Vf ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440: Vs + Vf <= 202924.977  
bw = 200.00

-----  
End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At local axis: 2

-----  
Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1  
At local axis: 2  
Integration Section: (a)  
Section Type: rdcs

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:  
Existing material of Secondary Member: Concrete Strength, fc = fcm = 18.00  
Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44  
Concrete Elasticity, Ec = 19940.411  
Steel Elasticity, Es = 200000.00  
Max Height, Hmax = 450.00  
Min Height, Hmin = 200.00  
Max Width, Wmax = 450.00

Min Width,  $W_{min} = 200.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_b/l_d > 1$ )  
 No FRP Wrapping

#### Stepwise Properties

Bending Moment,  $M = -1.5806E+008$   
 Shear Force,  $V_2 = 33259.52$   
 Shear Force,  $V_3 = -2.78595$   
 Axial Force,  $F = -1.4054E+006$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $As_t = 1545.664$   
   -Compression:  $As_c = 2576.106$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $As_{t,ten} = 829.3805$   
   -Compression:  $As_{l,com} = 1746.726$   
   -Middle:  $As_{l,mid} = 1545.664$   
 Mean Diameter of Tension Reinforcement,  $Db_L = 18.66667$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = u = 0.02547129$   
 $u = y + p = 0.02547129$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.02547129$  ((4.29), Biskinis Phd))  
 $M_y = 3.8889E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) =  $6000.00$   
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 3.0536E+013$   
 $factor = 0.70$   
 $A_g = 140000.00$   
 $f_c' = 18.00$   
 $N = 1.4054E+006$   
 $E_c * I_g = 4.3623E+013$

#### Calculation of Yielding Moment $M_y$

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

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:  
 flange width,  $b = 450.00$   
 web width,  $b_w = 200.00$   
 flange thickness,  $t = 200.00$

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 9.8162474E-006$   
 with  $f_y = 444.44$   
 $d = 407.00$   
 $y = 0.44378431$   
 $A = 0.03977101$   
 $B = 0.02746764$   
 with  $pt = 0.00283171$   
 $pc = 0.00953713$   
 $pv = 0.00843933$

$N = 1.4054E+006$   
 $b = 450.00$   
 $\mu = 0.10565111$   
 $y_{comp} = 8.6108073E-006$   
 with  $f_c = 18.00$   
 $E_c = 19940.411$   
 $y = 0.46363116$   
 $A = -0.00110899$   
 $B = 0.01020151$   
 with  $E_s = 200000.00$   
 CONFIRMATION:  $y = 0.46363116 < t/d$

Calculation of ratio  $l_b/d$

Adequate Lap Length:  $l_b/d \geq 1$

- Calculation of  $p$  -

From table 10-8:  $p = 0.00$

with:

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

shear control ratio  $V_y E / V_{CoI} E = 1.14637$

$d = 407.00$

$s = 150.00$

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00283171$

$A_v = 78.53982$ , is the area of every stirrup

$L_{stir} = 1060.00$ , is the total Length of all stirrups parallel to loading (shear) direction

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

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

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

$NUD = 1.4054E+006$

$A_g = 140000.00$

$f_{cE} = 18.00$

$f_{yE} = f_{yE} = 444.44$

$p_l = \text{Area\_Tot\_Long\_Rein} / (b * d) = 0.02250488$

$b = 450.00$

$d = 407.00$

$f_{cE} = 18.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (a)

### Calculation No. 3

column C1, Floor 1

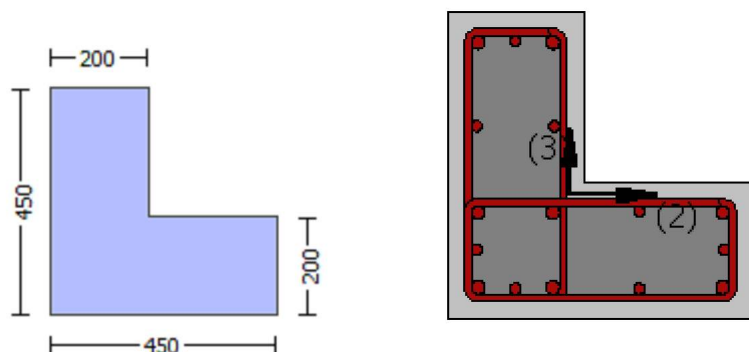
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rclcs

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:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 12.00$

Existing material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$

Concrete Elasticity,  $E_c = 19940.411$

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).

Existing material: Concrete Strength,  $f_c = f_{cm} = 18.00$

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

#####

Max Height,  $H_{max} = 450.00$

Min Height,  $H_{min} = 200.00$

Max Width,  $W_{max} = 450.00$

Min Width,  $W_{min} = 200.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_o/l_{ou,min} = l_b/l_d \geq 1$ )

No FRP Wrapping

Stepwise Properties

EDGE -A-  
 Bending Moment,  $M_a = -1.5806E+008$   
 Shear Force,  $V_a = -2.78595$   
 EDGE -B-  
 Bending Moment,  $M_b = 1.1240E+008$   
 Shear Force,  $V_b = 2.78595$   
 BOTH EDGES  
 Axial Force,  $F = -1.4054E+006$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $Asl_t = 1545.664$   
   -Compression:  $Asl_c = 2576.106$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $Asl_{ten} = 829.3805$   
   -Compression:  $Asl_{com} = 1746.726$   
   -Middle:  $Asl_{mid} = 1545.664$   
 Mean Diameter of Tension Reinforcement,  $DbL_{ten} = 18.66667$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $VR = *V_n = 206188.01$   
 $V_n ((10.3), ASCE 41-17) = knl * V_{ColO} = 206188.01$   
 $V_{Col} = 206188.01$   
 $knl = 1.00$   
 $displacement\_ductility\_demand = 0.42556495$

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

= 1 (normal-weight concrete)  
 $fc' = 12.00$ , but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $M_u = 1.5806E+008$   
 $V_u = 2.78595$   
 $d = 0.8 * h = 360.00$   
 $N_u = 1.4054E+006$   
 $A_g = 90000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 107711.748$   
 where:  
 $V_{s1} = 107711.748$  is calculated for section web, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 210.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.58333333$   
 $V_{s2} = 0.00$  is calculated for section flange, with:  
 $d = 160.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 210.00$   
 $V_{s2}$  is multiplied by  $Col2 = 0.00$   
 $s/d = 1.3125$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 165687.55$   
 $bw = 200.00$

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

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

From analysis, chord rotation  $\phi = 0.01083969$   
 $y = (My * Ls / 3) / Eleff = 0.02547129 ((4.29), Biskinis Phd))$   
 $My = 3.8889E+008$



$L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 6000.00  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 3.0536E+013$   
factor = 0.70  
 $A_g = 140000.00$   
 $f_c' = 18.00$   
 $N = 1.4054E+006$   
 $E_c \cdot I_g = 4.3623E+013$

Calculation of Yielding Moment  $M_y$

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

Assuming neutral axis within flange (  $y < t/d$ , compression zone rectangular) with:  
flange width,  $b = 450.00$   
web width,  $b_w = 200.00$   
flange thickness,  $t = 200.00$

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 9.8162474E-006$   
with  $f_y = 444.44$   
 $d = 407.00$   
 $y = 0.44378431$   
 $A = 0.03977101$   
 $B = 0.02746764$   
with  $p_t = 0.00452842$   
 $p_c = 0.00953713$   
 $p_v = 0.00843933$   
 $N = 1.4054E+006$   
 $b = 450.00$   
 $" = 0.10565111$   
 $y_{comp} = 8.6108073E-006$   
with  $f_c = 18.00$   
 $E_c = 19940.411$   
 $y = 0.46363116$   
 $A = -0.00110899$   
 $B = 0.01020151$   
with  $E_s = 200000.00$   
CONFIRMATION:  $y = 0.46363116 < t/d$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

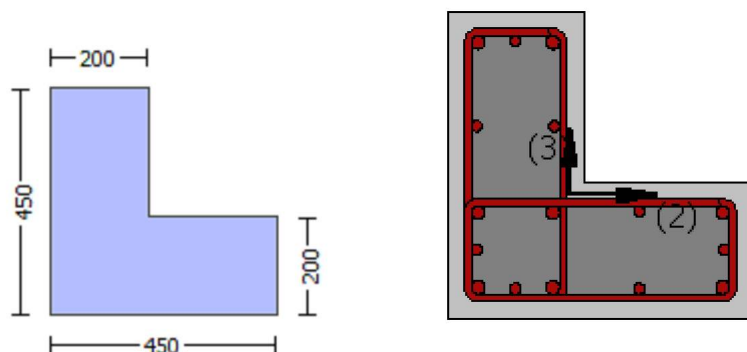
End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

## Calculation No. 4

column C1, Floor 1  
 Limit State: Operational Level (data interpolation between analysis steps 50 and 51)  
 Analysis: Uniform +X  
 Check: Chord rotation capacity (  $\phi$  )  
 Edge: Start  
 Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
 At Shear local axis: 3  
 (Bending local axis: 2)  
 Section Type: rclcs

#### Constant Properties

Knowledge Factor,  $\gamma = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 18.00$   
 Existing material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
 Concrete Elasticity,  $E_c = 19940.411$   
 Steel Elasticity,  $E_s = 200000.00$   
 #####  
 Note: Especially for the calculation of moment strengths,  
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$   
 #####  
 Max Height,  $H_{max} = 450.00$   
 Min Height,  $H_{min} = 200.00$   
 Max Width,  $W_{max} = 450.00$   
 Min Width,  $W_{min} = 200.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.00  
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_o/l_{ou,min} \geq 1$ )  
 No FRP Wrapping

#### Stepwise Properties

At local axis: 3  
 EDGE -A-

Shear Force,  $V_a = -8.8389216E-005$

EDGE -B-

Shear Force,  $V_b = 8.8389216E-005$

BOTH EDGES

Axial Force,  $F = -1.4060E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 829.3805$

-Compression:  $As_c = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

-Compression:  $As_{c,com} = 1746.726$

-Middle:  $As_{c,mid} = 1545.664$

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.14637$

Member Controlled by Shear ( $V_e/V_r > 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 263541.358$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 3.9531E+008$

$Mu_{1+} = 3.9531E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.8814E+008$ , 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 3.9531E+008$

$Mu_{2+} = 3.9531E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.8814E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $Mu_{1+}$

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

$\phi_u = 1.0666733E-005$

$M_u = 3.9531E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.42649604$

$N = 1.4060E+006$

$f_c = 18.00$

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

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00548378$

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

From (5.4b), TBDY:  $\phi_u = 0.00548378$

$\phi_{se} (5.4c) = 0.00245962$

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.09380979$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00283171$

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

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00283171$$

$$Lstir \text{ (Length of stirrups along Y)} = 1060.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 140000.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00283171$$

$$Lstir \text{ (Length of stirrups along X)} = 1060.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 140000.00$$

$$s = 210.00$$

$$fywe = 555.55$$

$$fce = 18.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

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

$$lo/lou,min = lb/ld = 1.00$$

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

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

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

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

$$\text{with } fs1 = fs = 555.55$$

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

$$y2 = 0.00231479$$

$$sh2 = 0.008$$

$$ft2 = 666.66$$

$$fy2 = 555.55$$

$$su2 = 0.032$$

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

$$lo/lou,min = lb/lb,min = 1.00$$

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

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

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

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

$$\text{with } fs2 = fs = 555.55$$

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

$$yv = 0.00231479$$

$$shv = 0.008$$

$$ftv = 666.66$$

$$fyv = 555.55$$

$$suv = 0.032$$

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

$$lo/lou,min = lb/ld = 1.00$$

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

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

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

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

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

$$\text{with } fsv = fs = 555.55$$

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.13976471$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.29435295$$

```

v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < s,y1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
--->
v* < v*s,c - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
--->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
--->
*cu (4.11) = 0.4973444
MRo (4.18) = 3.9531E+008
--->
u = cu (4.2) = 1.0666733E-005
Mu = MRo

```

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Calculation of ratio lb/d

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Adequate Lap Length: lb/d >= 1

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Calculation of Mu1-

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

u = 1.6699237E-005

$$\mu = 2.8814E+008$$

with full section properties:

$$b = 200.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$\nu = 0.95961609$$

$$N = 1.4060E+006$$

$$f_c = 18.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, \alpha) = 0.00548378$$

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

$$\text{From (5.4b), TB DY: } \mu = 0.00548378$$

$$\mu_e (5.4c) = 0.00245962$$

$$\alpha_e = \text{Max}(((\alpha_{\text{conf,max}} - \alpha_{\text{no conf}}) / \alpha_{\text{conf,max}}) * (\alpha_{\text{conf,min}} / \alpha_{\text{conf,max}}), 0) = 0.09380979$$

The definitions of  $\alpha_{\text{no conf}}$ ,  $\alpha_{\text{conf,min}}$  and  $\alpha_{\text{conf,max}}$  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.

$\alpha_{\text{conf,max}} = 89600.00$  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 perimeter hoops.

$\alpha_{\text{conf,min}} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $\alpha_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$\alpha_{\text{no conf}} = 54733.333$  is the unconfined core area which is equal to  $b^2/6$  as defined at (A.2).

$$\mu_{\text{sh,min}} = \text{Min}(\mu_{\text{sh,x}}, \mu_{\text{sh,y}}) = 0.00283171$$

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

$$\mu_{\text{sh,x}} ((5.4d), \text{TB DY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00283171$$

$$L_{\text{stir}} (\text{Length of stirrups along Y}) = 1060.00$$

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

$$A_{\text{sec}} (\text{section area}) = 140000.00$$

$$\mu_{\text{sh,y}} ((5.4d), \text{TB DY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00283171$$

$$L_{\text{stir}} (\text{Length of stirrups along X}) = 1060.00$$

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

$$A_{\text{sec}} (\text{section area}) = 140000.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 18.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \alpha_c = 0.002$$

$$\alpha_c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

$$l_o/l_{o,min} = l_b/l_d = 1.00$$

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

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

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, TB DY.

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

$$\text{with } fs_1 = fs = 555.55$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

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

and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_{b,min} = 1.00$   
 $\phi_{su2} = 0.4 \cdot \phi_{su2,nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $\phi_{su2,nominal} = 0.08$ ,  
For calculation of  $\phi_{su2,nominal}$  and  $\phi_{y2}, \phi_{sh2}, \phi_{ft2}, \phi_{fy2}$ , it is considered  
characteristic value  $\phi_{sy2} = \phi_{s2}/1.2$ , from table 5.1, TBDY.  
 $\phi_{y1}, \phi_{sh1}, \phi_{ft1}, \phi_{fy1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $\phi_{s2} = \phi_s = 555.55$   
with  $E_{s2} = E_s = 200000.00$   
 $\phi_{yv} = 0.00231479$   
 $\phi_{shv} = 0.008$   
 $\phi_{ftv} = 666.66$   
 $\phi_{fyv} = 555.55$   
 $\phi_{suv} = 0.032$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 1.00$   
 $\phi_{suv} = 0.4 \cdot \phi_{suv,nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $\phi_{suv,nominal} = 0.08$ ,  
considering characteristic value  $\phi_{fsv} = \phi_{sv}/1.2$ , from table 5.1, TBDY  
For calculation of  $\phi_{suv,nominal}$  and  $\phi_{yv}, \phi_{shv}, \phi_{ftv}, \phi_{fyv}$ , it is considered  
characteristic value  $\phi_{fsv} = \phi_{sv}/1.2$ , from table 5.1, TBDY.  
 $\phi_{y1}, \phi_{sh1}, \phi_{ft1}, \phi_{fy1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $\phi_{sv} = \phi_s = 555.55$   
with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (\phi_{s1}/\phi_c) = 0.66229413$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (\phi_{s2}/\phi_c) = 0.31447059$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (\phi_{sv}/\phi_c) = 0.58605883$   
and confined core properties:  
 $b = 140.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $\phi_{cc} (5A.2, TBDY) = 18.00$   
 $\phi_{cc} (5A.5, TBDY) = 0.002$   
 $\phi_c = \text{confinement factor} = 1.00$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (\phi_{s1}/\phi_c) = 1.02142$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (\phi_{s2}/\phi_c) = 0.48499254$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (\phi_{sv}/\phi_c) = 0.90384974$   
Case/Assumption: Unconfined full section - Steel rupture  
' does not satisfy Eq. (4.3)  
--->  
 $v < v_{s,c}$  - RHS eq.(4.5) is not satisfied  
--->  
Case/Assumption Rejected.  
--->  
New Case/Assumption: Unconfined full section - Spalling of concrete cover  
' satisfies Eq. (4.4)  
--->  
 $v < s_{y1}$  - LHS eq.(4.7) is not satisfied  
--->  
 $v < v_{c,y1}$  - RHS eq.(4.6) is not satisfied  
--->  
 $\phi_{cu} (4.11) = 0.80684338$   
 $M_{Rc} (4.18) = 2.8814E+008$   
--->  
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover  
In expressions below, the following modifications have been made  
-  $b, d, d'$  replaced by geometric parameters of the core:  $b_o, d_o, d'_o$   
-  $N_1, N_2, v$  normalised to  $b_o \cdot d_o$ , instead of  $b \cdot d$   
-  $\phi_{cc}, \phi_{cc}$  parameters of confined concrete,  $\phi_{cc}, \phi_{cc}$ , used in lieu of  $\phi_c, \phi_{cu}$   
--->  
Subcase: Rupture of tension steel  
--->  
 $v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied  
--->

$v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

$v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied

--->

$v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied

--->

$*c_u(4.11) = 0.98280667$

$M_{Ro}(4.18) = 1.3661E+008$

$M_{Ro} < 0.8 * M_{Rc}$

--->

$u = c_u$  (unconfined full section) =  $1.6699237E-005$

$\mu = M_{Rc}$

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of  $\mu_{2+}$

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

$u = 1.0666733E-005$

$\mu = 3.9531E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.42649604$

$N = 1.4060E+006$

$f_c = 18.00$

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

Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, \alpha) = 0.00548378$

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

From (5.4b), TBDY:  $c_u = 0.00548378$

$w_e(5.4c) = 0.00245962$

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.09380979$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00283171$

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

$p_{sh,x}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along Y) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$p_{sh,y}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along X) = 1060.00



Astir (stirrups area) = 78.53982  
Asec (section area) = 140000.00

s = 210.00

fywe = 555.55

fce = 18.00

From ((5.A.5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

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

lo/lou,min = lb/lb = 1.00

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 = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

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

lo/lou,min = lb/lb,min = 1.00

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 = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

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

lo/lou,min = lb/lb = 1.00

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 = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.13976471

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.29435295

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.26047059

and confined core properties:

b = 390.00

d = 377.00

d' = 13.00

fcc (5A.2, TBDY) = 18.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

```

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.4973444
MRo (4.18) = 3.9531E+008
---->
u = cu (4.2) = 1.0666733E-005
Mu = MRo
-----

Calculation of ratio lb/d
-----
Adequate Lap Length: lb/d >= 1
-----
-----

Calculation of Mu2-
-----
-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.6699237E-005
Mu = 2.8814E+008
-----

with full section properties:
b = 200.00
d = 407.00
d' = 43.00
v = 0.95961609
N = 1.4060E+006

```

$f_c = 18.00$   
 $c_o (5A.5, TBDY) = 0.002$   
 Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.00548378$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $c_u = 0.00548378$   
 $w_e (5.4c) = 0.00245962$   
 $a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$   
 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.  
 $A_{conf,max} = 89600.00$  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 perimeter hoops.  
 $A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.  
 $A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00283171$   
 Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$   
 $L_{stir}$  (Length of stirrups along Y) = 1060.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 140000.00

$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$   
 $L_{stir}$  (Length of stirrups along X) = 1060.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 140000.00

$s = 210.00$   
 $f_{ywe} = 555.55$   
 $f_{ce} = 18.00$

From ((5.A5), TBDY), TBDY:  $c_c = 0.002$   
 $c = \text{confinement factor} = 1.00$

$y_1 = 0.00231479$   
 $sh_1 = 0.008$   
 $ft_1 = 666.66$   
 $fy_1 = 555.55$   
 $su_1 = 0.032$

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

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

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

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

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

with  $fs_1 = fs = 555.55$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$   
 $sh_2 = 0.008$   
 $ft_2 = 666.66$   
 $fy_2 = 555.55$   
 $su_2 = 0.032$

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

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

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

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

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

```

with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.66229413
2 = Asl,com/(b*d)*(fs2/fc) = 0.31447059
v = Asl,mid/(b*d)*(fsv/fc) = 0.58605883
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < s,y1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is not satisfied
--->
cu (4.11) = 0.80684338
MRc (4.18) = 2.8814E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
--->
v* < v*s,c - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
--->

```

$v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied

--->

$*c_u(4.11) = 0.98280667$

$M_{Ro}(4.18) = 1.3661E+008$

$M_{Ro} < 0.8*M_{Rc}$

--->

$u = c_u$  (unconfined full section) =  $1.6699237E-005$

$M_u = M_{Rc}$

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 229892.529$

Calculation of Shear Strength at edge 1,  $V_{r1} = 229892.529$

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

$V_{Col0} = 229892.529$

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

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

= 1 (normal-weight concrete)

$f'_c = 18.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$M_u = 1.2877E+008$

$V_u = 8.8389216E-005$

$d = 0.8*h = 360.00$

$N_u = 1.4060E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$

where:

$V_{s1} = 119678.523$  is calculated for section web, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$s/d = 0.58333333$

$V_{s2} = 0.00$  is calculated for section flange, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

$V_{s2}$  is multiplied by  $Col2 = 0.00$

$s/d = 1.3125$

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

From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$

$b_w = 200.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 229892.529$

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

$V_{Col0} = 229892.529$

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

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

= 1 (normal-weight concrete)

$f'_c = 18.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.1237E+008$   
 $V_u = 8.8389216E-005$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 1.4060E+006$   
 $A_g = 90000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$   
 where:  
 $V_{s1} = 119678.523$  is calculated for section web, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 210.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.58333333$   
 $V_{s2} = 0.00$  is calculated for section flange, with:  
 $d = 160.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 210.00$   
 $V_{s2}$  is multiplied by  $Col2 = 0.00$   
 $s/d = 1.3125$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$   
 $b_w = 200.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
 At local axis: 3  
 -----

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
 At Shear local axis: 2  
 (Bending local axis: 3)  
 Section Type: rdlcs

#### Constant Properties

-----  
 Knowledge Factor,  $\phi = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 18.00$   
 Existing material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
 Concrete Elasticity,  $E_c = 19940.411$   
 Steel Elasticity,  $E_s = 200000.00$   
 #####  
 Note: Especially for the calculation of moment strengths,  
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$   
 #####  
 Max Height,  $H_{max} = 450.00$   
 Min Height,  $H_{min} = 200.00$   
 Max Width,  $W_{max} = 450.00$   
 Min Width,  $W_{min} = 200.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.00  
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_o/l_{ou,min} \geq 1$ )  
 No FRP Wrapping  
 -----

## Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = 3.7569140E-005$

EDGE -B-

Shear Force,  $V_b = -3.7569140E-005$

BOTH EDGES

Axial Force,  $F = -1.4060E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 829.3805$

-Compression:  $As_c = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 1746.726$

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

-Middle:  $As_{l,mid} = 1545.664$

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.14637$

Member Controlled by Shear ( $V_e/V_r > 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 263541.358$   
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 3.9531E+008$

$\mu_{1+} = 2.8814E+008$ , 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

$\mu_{1-} = 3.9531E+008$ , 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 3.9531E+008$

$\mu_{2+} = 2.8814E+008$ , 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

$\mu_{2-} = 3.9531E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $\mu_{1+}$

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

$\phi_u = 1.6699237E-005$

$\mu_u = 2.8814E+008$

with full section properties:

$b = 200.00$

$d = 407.00$

$d' = 43.00$

$\nu = 0.95961609$

$N = 1.4060E+006$

$f_c = 18.00$

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

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_0) = 0.00548378$

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

From (5.4b), TBDY:  $\phi_u = 0.00548378$

$\phi_{ue}$  (5.4c) = 0.00245962

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.09380979$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

AnoConf = 54733.333 is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh,min = \text{Min}(psh,x, psh,y) = 0.00283171$   
 Expression ((5.4d), TBDY) for  $psh,min$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $psh,x ((5.4d), TBDY) = Lstir \cdot Astir / (Asec \cdot s) = 0.00283171$   
 $Lstir$  (Length of stirrups along Y) = 1060.00  
 $Astir$  (stirrups area) = 78.53982  
 $Asec$  (section area) = 140000.00  
 -----

$psh,y ((5.4d), TBDY) = Lstir \cdot Astir / (Asec \cdot s) = 0.00283171$   
 $Lstir$  (Length of stirrups along X) = 1060.00  
 $Astir$  (stirrups area) = 78.53982  
 $Asec$  (section area) = 140000.00  
 -----

$s = 210.00$   
 $fywe = 555.55$   
 $fce = 18.00$   
 From ((5.A5), TBDY), TBDY:  $cc = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $y1 = 0.00231479$   
 $sh1 = 0.008$   
 $ft1 = 666.66$   
 $fy1 = 555.55$   
 $su1 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou,min = lb/ld = 1.00$   
 $su1 = 0.4 \cdot esu1\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
 For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs1 = fs = 555.55$   
 with  $Es1 = Es = 200000.00$   
 $y2 = 0.00231479$   
 $sh2 = 0.008$   
 $ft2 = 666.66$   
 $fy2 = 555.55$   
 $su2 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou,min = lb/lb,min = 1.00$   
 $su2 = 0.4 \cdot esu2\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
 For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs2 = fs = 555.55$   
 with  $Es2 = Es = 200000.00$   
 $yv = 0.00231479$   
 $shv = 0.008$   
 $ftv = 666.66$   
 $fyv = 555.55$   
 $suv = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou,min = lb/ld = 1.00$   
 $suv = 0.4 \cdot esuv\_nominal ((5.5), TBDY) = 0.032$   
 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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.66229413
2 = Asl,com/(b*d)*(fs2/fc) = 0.31447059
v = Asl,mid/(b*d)*(fsv/fc) = 0.58605883
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is not satisfied
--->
cu (4.11) = 0.80684338
MRc (4.18) = 2.8814E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N1, N2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
--->
v* < v*sc - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
--->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
--->
*cu (4.11) = 0.98280667
MRo (4.18) = 1.3661E+008
MRo < 0.8*MRc
--->
u = cu (unconfined full section) = 1.6699237E-005
Mu = MRc

```

-----

Calculation of ratio lb/d

-----

Adequate Lap Length: lb/d >= 1

-----

-----

-----

Calculation of Mu1-

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

$$u = 1.0666733E-005$$

$$\mu = 3.9531E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$\nu = 0.42649604$$

$$N = 1.4060E+006$$

$$f_c = 18.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00548378$$

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

$$\text{From (5.4b), TB DY: } \phi_u = 0.00548378$$

$$\phi_{ue} (5.4c) = 0.00245962$$

$$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00283171$$

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

$$\phi_{sh,x} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$\phi_{sh,y} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along X}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 18.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \phi_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_1_{nominal} ((5.5), \text{TB DY}) = 0.032$$

$$\text{From table 5A.1, TB DY: } esu_1_{nominal} = 0.08,$$

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, TB DY.

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

$$\text{with } fs_1 = fs = 555.55$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00231479$$

```

sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
    using (30) in Biskinis/Fardis (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 = 1.00
    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 = 555.55
    with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (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 = 1.00
    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 = 555.55
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu

```

```

---->
Subcase: Rupture of tension steel
---->
 $v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied
---->
 $v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
 $v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied
---->
 $v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied
---->
 $\epsilon_{cu}$  (4.11) = 0.4973444
MRo (4.18) = 3.9531E+008
---->
 $u = \epsilon_{cu}$  (4.2) = 1.0666733E-005
Mu = MRo
-----

Calculation of ratio lb/d
-----
Adequate Lap Length: lb/d >= 1
-----
-----
-----
Calculation of Mu2+
-----
-----
-----
Calculation of ultimate curvature  $\epsilon_u$  according to 4.1, Biskinis/Fardis 2013:
 $\epsilon_u = 1.6699237E-005$ 
Mu = 2.8814E+008
-----

with full section properties:
b = 200.00
d = 407.00
d' = 43.00
v = 0.95961609
N = 1.4060E+006
fc = 18.00
 $\omega$  (5A.5, TBDY) = 0.002
Final value of  $\epsilon_{cu}$ :  $\epsilon_{cu}^* = \text{shear\_factor} * \text{Max}(\epsilon_{cu}, \epsilon_{cc}) = 0.00548378$ 
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY:  $\epsilon_{cu} = 0.00548378$ 
 $\epsilon_{se}$  (5.4c) = 0.00245962
 $\epsilon_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$ 
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,max = 89600.00 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 perimeter hoops.
Aconf,min = 21600.00 is the confined core area at midway between the levels of hoops and
is calculated by reducing all the dimensions of the area Aconf,max by a length
equal to half the clear spacing between hoops.
AnoConf = 54733.333 is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).
 $\epsilon_{psh,min} = \text{Min}(\epsilon_{psh,x}, \epsilon_{psh,y}) = 0.00283171$ 
Expression ((5.4d), TBDY) for  $\epsilon_{psh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without
earthquake detailing (90° closed stirrups)
-----
 $\epsilon_{psh,x}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$ 
Lstir (Length of stirrups along Y) = 1060.00
Astir (stirrups area) = 78.53982

```

Asec (section area) = 140000.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00283171

Lstir (Length of stirrups along X) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

s = 210.00

fywe = 555.55

fce = 18.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

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

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

Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

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 = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

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

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

Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

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 = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.66229413

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.31447059

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.58605883

and confined core properties:

b = 140.00

d = 377.00

```

d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
  c = confinement factor = 1.00
  1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
  2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
  v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.80684338
MRc (4.18) = 2.8814E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.98280667
MRo (4.18) = 1.3661E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 1.6699237E-005
Mu = MRc
-----

Calculation of ratio lb/d
-----

Adequate Lap Length: lb/d >= 1
-----

Calculation of Mu2-
-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.0666733E-005
Mu = 3.9531E+008
-----

with full section properties:

```

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.42649604$   
 $N = 1.4060E+006$   
 $f_c = 18.00$   
 $\phi (5A.5, \text{TB DY}) = 0.002$   
 Final value of  $\phi$ :  $\phi^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00548378$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TB DY:  $\phi_u = 0.00548378$   
 $\phi_w (5.4c) = 0.00245962$   
 $\phi_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$   
 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.  
 $A_{conf,max} = 89600.00$  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 perimeter hoops.  
 $A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.  
 $A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i d_i / 6$  as defined at (A.2).  
 $\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00283171$   
 Expression ((5.4d), TB DY) for  $\phi_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

---

$\phi_{sh,x} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$   
 $L_{stir}$  (Length of stirrups along Y) = 1060.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 140000.00

---

$\phi_{sh,y} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$   
 $L_{stir}$  (Length of stirrups along X) = 1060.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 140000.00

---

$s = 210.00$   
 $f_{ywe} = 555.55$   
 $f_{ce} = 18.00$   
 From ((5A.5), TB DY), TB DY:  $\phi_c = 0.002$   
 $\phi_c$  = confinement factor = 1.00  
 $y_1 = 0.00231479$   
 $sh_1 = 0.008$   
 $ft_1 = 666.66$   
 $fy_1 = 555.55$   
 $su_1 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $l_o / l_{ou,min} = l_b / l_d = 1.00$   
 $su_1 = 0.4 * esu_1_{nominal} ((5.5), \text{TB DY}) = 0.032$   
 From table 5A.1, TB DY:  $esu_1_{nominal} = 0.08$ ,  
 For calculation of  $esu_1_{nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = f_s / 1.2$ , from table 5.1, TB DY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_1 = f_s = 555.55$   
 with  $Es_1 = E_s = 200000.00$   
 $y_2 = 0.00231479$   
 $sh_2 = 0.008$   
 $ft_2 = 666.66$   
 $fy_2 = 555.55$   
 $su_2 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $l_o / l_{ou,min} = l_b / l_{b,min} = 1.00$

```

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 = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
--->
v* < v*s,c - LHS eq.(4.5) is not satisfied
--->
Subcase rejected

```



--->  
New Subcase: Failure of compression zone

--->  
 $v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied

--->  
 $v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied

--->  
 $\mu_{cu}(4.11) = 0.4973444$   
 $M_{Ro}(4.18) = 3.9531E+008$

--->  
 $u = \mu_{cu}(4.2) = 1.0666733E-005$   
 $\mu_u = M_{Ro}$

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

-----  
Adequate Lap Length:  $l_b/l_d \geq 1$

-----  
Calculation of Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 229892.529$

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 229892.529$

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

$V_{ColO} = 229892.529$

$knl = 1$  (zero step-static loading)

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

-----  
 $= 1$  (normal-weight concrete)  
 $f'_c = 18.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 1.2440E+008$   
 $\mu_u = 3.7569140E-005$   
 $d = 0.8 * h = 360.00$   
 $N_u = 1.4060E+006$   
 $A_g = 90000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$   
where:  
 $V_{s1} = 0.00$  is calculated for section web, with:  
 $d = 160.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 210.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.00$   
 $s/d = 1.3125$   
 $V_{s2} = 119678.523$  is calculated for section flange, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 210.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.58333333$   
 $V_f((11-3)-(11.4), ACI 440) = 0.00$   
From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$   
 $bw = 200.00$

-----  
Calculation of Shear Strength at edge 2,  $V_{r2} = 229892.529$

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

$V_{ColO} = 229892.529$

$knl = 1$  (zero step-static loading)

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

= 1 (normal-weight concrete)  
 $f'_c = 18.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 1.0841E+008$   
 $V_u = 3.7569140E-005$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 1.4060E+006$   
 $A_g = 90000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$   
 where:  
 $V_{s1} = 0.00$  is calculated for section web, with:  
 $d = 160.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 210.00$   
 $V_{s1}$  is multiplied by  $\text{Col1} = 0.00$   
 $s/d = 1.3125$   
 $V_{s2} = 119678.523$  is calculated for section flange, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 210.00$   
 $V_{s2}$  is multiplied by  $\text{Col2} = 1.00$   
 $s/d = 0.58333333$   
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$   
 $b_w = 200.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
 At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1  
 At local axis: 3  
 Integration Section: (a)  
 Section Type: rclcs

#### 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:  
 Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 18.00$   
 Existing material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
 Concrete Elasticity,  $E_c = 19940.411$   
 Steel Elasticity,  $E_s = 200000.00$   
 Max Height,  $H_{max} = 450.00$   
 Min Height,  $H_{min} = 200.00$   
 Max Width,  $W_{max} = 450.00$   
 Min Width,  $W_{min} = 200.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_b/l_d \geq 1$ )  
 No FRP Wrapping

#### Stepwise Properties

Bending Moment,  $M = -1.8641\text{E}+008$   
 Shear Force,  $V2 = 33259.52$   
 Shear Force,  $V3 = -2.78595$   
 Axial Force,  $F = -1.4054\text{E}+006$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
     -Tension:  $As_t = 1545.664$   
     -Compression:  $As_c = 2576.106$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
     -Tension:  $As_{ten} = 1746.726$   
     -Compression:  $As_{com} = 829.3805$   
     -Middle:  $As_{mid} = 1545.664$   
 Mean Diameter of Tension Reinforcement,  $Db_L = 17.71429$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = \frac{1}{2} u = 0.01235126$   
 $u = y + p = 0.01235126$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.01235126$  ((4.29), Biskinis Phd))  
 $M_y = 2.0187\text{E}+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 5604.816  
 From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} * E_c * I_g = 3.0536\text{E}+013$   
     factor = 0.70  
      $A_g = 140000.00$   
      $f_c' = 18.00$   
      $N = 1.4054\text{E}+006$   
      $E_c * I_g = 4.3623\text{E}+013$

Calculation of Yielding Moment  $M_y$

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

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 1.3705819\text{E}-005$   
 with  $f_y = 444.44$   
      $d = 407.00$   
      $y = 0.60163265$   
      $A = 0.08948478$   
      $B = 0.07188114$   
     with  $p_t = 0.00283171$   
          $p_c = 0.01018895$   
          $p_v = 0.0189885$   
          $N = 1.4054\text{E}+006$   
          $b = 200.00$   
          $\rho = 0.10565111$   
      $y_{comp} = 4.7559098\text{E}-006$   
 with  $f_c = 18.00$   
      $E_c = 19940.411$   
      $y = 0.8394269$   
      $A = -0.00249523$   
      $B = 0.03303234$   
     with  $E_s = 200000.00$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

- Calculation of  $p$  -

From table 10-8:  $p = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because  $l_b/d \geq 1$   
shear control ratio  $V_{yE}/V_{Col0E} = 1.14637$

$d = 407.00$

$s = 150.00$

$t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.00283171$

$A_v = 78.53982$ , is the area of every stirrup

$L_{stir} = 1060.00$ , is the total Length of all stirrups parallel to loading (shear) direction

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

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

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

$NUD = 1.4054E+006$

$A_g = 140000.00$

$f_{cE} = 18.00$

$f_{yE} = f_{yI} = 444.44$

$p_l = \text{Area\_Tot\_Long\_Rein}/(b*d) = 0.05063599$

$b = 200.00$

$d = 407.00$

$f_{cE} = 18.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

## Calculation No. 5

column C1, Floor 1

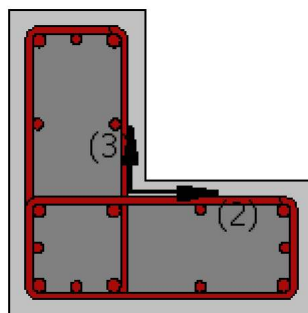
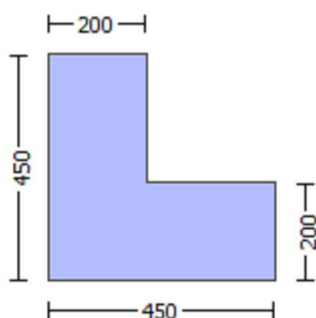
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1  
At local axis: 2  
Integration Section: (b)  
Section Type: rdcs

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:  
Existing material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 12.00$   
Existing material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$   
Concrete Elasticity,  $E_c = 19940.411$   
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).  
Existing material: Concrete Strength,  $f_c = f_{cm} = 18.00$   
Existing material: Steel Strength,  $f_s = f_{sm} = 444.44$   
#####  
Max Height,  $H_{max} = 450.00$   
Min Height,  $H_{min} = 200.00$   
Max Width,  $W_{max} = 450.00$   
Min Width,  $W_{min} = 200.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Secondary Member  
Smooth Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Adequate Lap Length ( $l_o/l_{ou,min} = l_b/l_d \geq 1$ )  
No FRP Wrapping

---

Stepwise Properties

---

EDGE -A-  
Bending Moment,  $M_a = -1.8641E+008$   
Shear Force,  $V_a = 33259.52$   
EDGE -B-  
Bending Moment,  $M_b = 1.1506E+008$   
Shear Force,  $V_b = -33259.52$   
BOTH EDGES  
Axial Force,  $F = -1.4054E+006$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 829.3805$   
-Compression:  $A_{sc} = 3292.389$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten} = 1746.726$   
-Compression:  $A_{st,com} = 829.3805$   
-Middle:  $A_{st,mid} = 1545.664$   
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 17.71429$

---



---

Existing component: From table 7-7, ASCE 41-17: Final Shear Capacity  $V_R = \phi V_n = 206188.01$   
 $V_n$  ((10-3), ASCE 41-17) =  $k_n \phi V_{CoI} = 206188.01$   
 $V_{CoI} = 206188.01$   
 $k_n = 1.00$   
displacement\_ductility\_demand = 0.58005952

---

NOTE: In expression (10-3) ' $V_s$ ' is replaced by ' $V_{s+} + \phi V_f$ '  
where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$  (normal-weight concrete)  
 $f'_c = 12.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 1.1506E+008$   
 $V_u = 33259.52$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 1.4054E+006$   
 $A_g = 90000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 107711.748$   
 where:  
 $V_{s1} = 0.00$  is calculated for section web, with:  
 $d = 160.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 210.00$   
 $V_{s1}$  is multiplied by  $\text{Col1} = 0.00$   
 $s/d = 1.3125$   
 $V_{s2} = 107711.748$  is calculated for section flange, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 210.00$   
 $V_{s2}$  is multiplied by  $\text{Col2} = 1.00$   
 $s/d = 0.58333333$   
 $V_f ((11-3)-(11.4), \text{ACI 440}) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 165687.55$   
 $b_w = 200.00$

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

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

From analysis, chord rotation  $\theta_r = 0.00442203$   
 $y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00762341$  ((4.29), Biskinis Phd))  
 $M_y = 2.0187E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 3459.388  
 From table 10.5, ASCE 41\_17:  $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 3.0536E+013$   
 $\text{factor} = 0.70$   
 $A_g = 140000.00$   
 $f'_c = 18.00$   
 $N = 1.4054E+006$   
 $E_c \cdot I_g = 4.3623E+013$

Calculation of Yielding Moment  $M_y$

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

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$   
 $y_{\text{ten}} = 1.3705819E-005$   
 with  $f_y = 444.44$   
 $d = 407.00$   
 $y = 0.60163265$   
 $A = 0.08948478$   
 $B = 0.07188114$   
 with  $p_t = 0.02145854$   
 $p_c = 0.01018895$   
 $p_v = 0.0189885$   
 $N = 1.4054E+006$   
 $b = 200.00$   
 $\lambda = 0.10565111$   
 $y_{\text{comp}} = 4.7559098E-006$

with  $f_c = 18.00$   
 $E_c = 19940.411$   
 $y = 0.8394269$   
 $A = -0.00249523$   
 $B = 0.03303234$   
with  $E_s = 200000.00$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 6

column C1, Floor 1

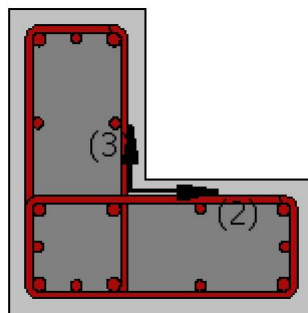
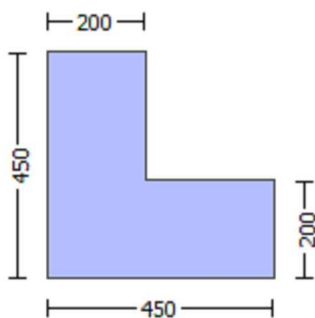
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\mu$  )

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rdcS

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 18.00$

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

Concrete Elasticity,  $E_c = 19940.411$   
 Steel Elasticity,  $E_s = 200000.00$   
 #####  
 Note: Especially for the calculation of moment strengths,  
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$   
 #####  
 Max Height,  $H_{max} = 450.00$   
 Min Height,  $H_{min} = 200.00$   
 Max Width,  $W_{max} = 450.00$   
 Min Width,  $W_{min} = 200.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.00  
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_o/l_{ou,min} \geq 1$ )  
 No FRP Wrapping

#### Stepwise Properties

At local axis: 3  
 EDGE -A-  
 Shear Force,  $V_a = -8.8389216E-005$   
 EDGE -B-  
 Shear Force,  $V_b = 8.8389216E-005$   
 BOTH EDGES  
 Axial Force,  $F = -1.4060E+006$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{sl,t} = 829.3805$   
   -Compression:  $A_{sl,c} = 3091.327$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{sl,ten} = 829.3805$   
   -Compression:  $A_{sl,com} = 1746.726$   
   -Middle:  $A_{sl,mid} = 1545.664$

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.14637$   
 Member Controlled by Shear ( $V_e/V_r > 1$ )  
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 263541.358$   
 with  
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 3.9531E+008$   
 $\mu_{u1+} = 3.9531E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction  
 which is defined for the static loading combination  
 $\mu_{u1-} = 2.8814E+008$ , 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  
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 3.9531E+008$   
 $\mu_{u2+} = 3.9531E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction  
 which is defined for the static loading combination  
 $\mu_{u2-} = 2.8814E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment  
 direction which is defined for the static loading combination

#### Calculation of $\mu_{u1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\phi_u = 1.0666733E-005$   
 $\mu_u = 3.9531E+008$



with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.42649604$$

$$N = 1.4060E+006$$

$$f_c = 18.00$$

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

$$\text{Final value of } \phi: \phi^* = \text{shear\_factor} * \text{Max}(\phi, \phi_c) = 0.00548378$$

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

$$\text{From (5.4b), TB DY: } \phi = 0.00548378$$

$$\phi_e (5.4c) = 0.00245962$$

$$\phi_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i d/6$  as defined at (A.2).

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00283171$$

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

$$\phi_{sh,x} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$\phi_{sh,y} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along X}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 18.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \phi_c = 0.002$$

$$\phi = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

$$l_o / l_{ou,min} = l_b / l_d = 1.00$$

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

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

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, TB DY.

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

$$\text{with } fs_1 = fs = 555.55$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (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 = 1.00
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 = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (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 = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->

```

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

$v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied

--->

$v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied

--->

$\epsilon_{cu} (4.11) = 0.4973444$

$M_{Ro} (4.18) = 3.9531E+008$

--->

$u = \epsilon_{cu} (4.2) = 1.0666733E-005$

$\mu_u = M_{Ro}$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

Calculation of  $\mu_{u1}$ -

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

$\epsilon_u = 1.6699237E-005$

$\mu_u = 2.8814E+008$

with full section properties:

$b = 200.00$

$d = 407.00$

$d' = 43.00$

$v = 0.95961609$

$N = 1.4060E+006$

$f_c = 18.00$

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

Final value of  $\epsilon_{cu}$ :  $\epsilon_{cu}^* = \text{shear\_factor} * \text{Max}(\epsilon_{cu}, \epsilon_{cc}) = 0.00548378$

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

From (5.4b), TBDY:  $\epsilon_{cu} = 0.00548378$

$\epsilon_{we} (5.4c) = 0.00245962$

$\epsilon_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.09380979$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\epsilon_{psh,min} = \text{Min}(\epsilon_{psh,x}, \epsilon_{psh,y}) = 0.00283171$

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

$\epsilon_{psh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along Y) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$\epsilon_{psh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along X) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$s = 210.00$   
 $f_{ywe} = 555.55$   
 $f_{ce} = 18.00$   
 From ((5.A.5), TBDY), TBDY:  $cc = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $y_1 = 0.00231479$   
 $sh_1 = 0.008$   
 $ft_1 = 666.66$   
 $fy_1 = 555.55$   
 $su_1 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/ld = 1.00$   
 $su_1 = 0.4 * esu_1, \text{nominal} ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esu_1, \text{nominal} = 0.08$ ,  
 For calculation of  $esu_1, \text{nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
 characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_1 = fs = 555.55$   
 with  $Es_1 = Es = 200000.00$   
 $y_2 = 0.00231479$   
 $sh_2 = 0.008$   
 $ft_2 = 666.66$   
 $fy_2 = 555.55$   
 $su_2 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/lb, \min = 1.00$   
 $su_2 = 0.4 * esu_2, \text{nominal} ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esu_2, \text{nominal} = 0.08$ ,  
 For calculation of  $esu_2, \text{nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = fs = 555.55$   
 with  $Es_2 = Es = 200000.00$   
 $y_v = 0.00231479$   
 $sh_v = 0.008$   
 $ft_v = 666.66$   
 $fy_v = 555.55$   
 $suv = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/ld = 1.00$   
 $suv = 0.4 * esuv, \text{nominal} ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esuv, \text{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv, \text{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = fs = 555.55$   
 with  $Es_v = Es = 200000.00$   
 $1 = A_{sl, \text{ten}} / (b * d) * (fs_1 / fc) = 0.66229413$   
 $2 = A_{sl, \text{com}} / (b * d) * (fs_2 / fc) = 0.31447059$   
 $v = A_{sl, \text{mid}} / (b * d) * (fs_v / fc) = 0.58605883$   
 and confined core properties:  
 $b = 140.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, \text{TBDY}) = 18.00$   
 $cc (5A.5, \text{TBDY}) = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = A_{sl, \text{ten}} / (b * d) * (fs_1 / fc) = 1.02142$   
 $2 = A_{sl, \text{com}} / (b * d) * (fs_2 / fc) = 0.48499254$   
 $v = A_{sl, \text{mid}} / (b * d) * (fs_v / fc) = 0.90384974$

Case/Assumption: Unconfined full section - Steel rupture  
' does not satisfy Eq. (4.3)

--->  
 $v < v_{s,c}$  - RHS eq.(4.5) is not satisfied

Case/Assumption Rejected.

--->  
New Case/Assumption: Unconfined full section - Spalling of concrete cover  
' satisfies Eq. (4.4)

--->  
 $v < s_{y1}$  - LHS eq.(4.7) is not satisfied

--->  
 $v < v_{c,y1}$  - RHS eq.(4.6) is not satisfied

--->  
 $c_u$  (4.11) = 0.80684338  
 $M_{Rc}$  (4.18) = 2.8814E+008

--->  
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- $b$ ,  $d$ ,  $d'$  replaced by geometric parameters of the core:  $b_o$ ,  $d_o$ ,  $d'_o$
- $N$ ,  $1$ ,  $2$ ,  $v$  normalised to  $b_o*d_o$ , instead of  $b*d$
- parameters of confined concrete,  $f_{cc}$ ,  $c_c$ , used in lieu of  $f_c$ ,  $c_u$

--->  
Subcase: Rupture of tension steel

--->  
 $v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied

--->  
 $v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied

--->  
Subcase rejected

--->  
New Subcase: Failure of compression zone

--->  
 $v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied

--->  
 $v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied

--->  
 $*c_u$  (4.11) = 0.98280667  
 $M_{Ro}$  (4.18) = 1.3661E+008

$M_{Ro} < 0.8*M_{Rc}$

--->  
 $u = c_u$  (unconfined full section) = 1.6699237E-005  
 $M_u = M_{Rc}$

-----  
Calculation of ratio  $l_b/d$

-----  
Adequate Lap Length:  $l_b/d \geq 1$

-----  
Calculation of  $M_{u2+}$

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

$u = 1.0666733E-005$   
 $M_u = 3.9531E+008$

-----  
with full section properties:

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.42649604$   
 $N = 1.4060E+006$   
 $f_c = 18.00$   
 $c_o$  (5A.5, TBDY) = 0.002

Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00548378$   
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY:  $cu = 0.00548378$   
 $we$  (5.4c) = 0.00245962  
 $ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$   
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.  
 $A_{conf,max} = 89600.00$  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 perimeter hoops.  
 $A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.  
 $A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh,min = \text{Min}(psh,x, psh,y) = 0.00283171$   
Expression ((5.4d), TBDY) for  $psh,min$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh,x$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$   
 $L_{stir}$  (Length of stirrups along Y) = 1060.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 140000.00

$psh,y$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$   
 $L_{stir}$  (Length of stirrups along X) = 1060.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 140000.00

$s = 210.00$   
 $fy_{we} = 555.55$   
 $f_{ce} = 18.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.002$   
 $c = \text{confinement factor} = 1.00$

$y1 = 0.00231479$   
 $sh1 = 0.008$   
 $ft1 = 666.66$   
 $fy1 = 555.55$   
 $su1 = 0.032$

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

$lo/lo_{u,min} = lb/ld = 1.00$

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

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  $fs1 = fs = 555.55$

with  $Es1 = Es = 200000.00$

$y2 = 0.00231479$   
 $sh2 = 0.008$   
 $ft2 = 666.66$   
 $fy2 = 555.55$   
 $su2 = 0.032$

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

$lo/lo_{u,min} = lb/lb_{min} = 1.00$

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

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  $fs2 = fs = 555.55$

with  $Es2 = Es = 200000.00$

```

yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
    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 = 555.55
    with Esv = Es = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
    2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
    v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
    2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
    v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->

```

$$*cu(4.11) = 0.4973444$$

$$MRo(4.18) = 3.9531E+008$$

--->

$$u = cu(4.2) = 1.0666733E-005$$

$$Mu = MRo$$

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

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

$$u = 1.6699237E-005$$

$$Mu = 2.8814E+008$$

with full section properties:

$$b = 200.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.95961609$$

$$N = 1.4060E+006$$

$$fc = 18.00$$

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

$$\text{Final value of } cu: cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00548378$$

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

$$\text{From (5.4b), TBDY: } cu = 0.00548378$$

$$we(5.4c) = 0.00245962$$

$$ase = \text{Max}(((Aconf,max - AnoConf)/Aconf,max) * (Aconf,min/Aconf,max), 0) = 0.09380979$$

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,max = 89600.00 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 perimeter hoops.

Aconf,min = 21600.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 54733.333 is the unconfined core area which is equal to  $bi^2/6$  as defined at (A.2).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00283171$$

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

$$psh,x((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00283171$$

$$Lstir(\text{Length of stirrups along Y}) = 1060.00$$

$$Astir(\text{stirrups area}) = 78.53982$$

$$Asec(\text{section area}) = 140000.00$$

$$psh,y((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00283171$$

$$Lstir(\text{Length of stirrups along X}) = 1060.00$$

$$Astir(\text{stirrups area}) = 78.53982$$

$$Asec(\text{section area}) = 140000.00$$

$$s = 210.00$$

$$fywe = 555.55$$

$$fce = 18.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$



```

fy1 = 555.55
su1 = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 1.00
    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 = 555.55
    with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 1.00
    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 = 555.55
    with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 1.00
    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 = 555.55
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.66229413
2 = Asl,com/(b*d)*(fs2/fc) = 0.31447059
v = Asl,mid/(b*d)*(fsv/fc) = 0.58605883
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
    2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
    v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover

```

satisfies Eq. (4.4)

--->

$v < s_y1$  - LHS eq.(4.7) is not satisfied

--->

$v < v_{c,y1}$  - RHS eq.(4.6) is not satisfied

--->

$c_u$  (4.11) = 0.80684338

$M_{Rc}$  (4.18) = 2.8814E+008

--->

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- $b, d, d'$  replaced by geometric parameters of the core:  $b_o, d_o, d'_o$
- $N, \epsilon_1, \epsilon_2, v$  normalised to  $b_o*d_o$ , instead of  $b*d$
- $f_{cc}, \epsilon_{cc}$  parameters of confined concrete,  $f_{cc}, \epsilon_{cc}$  used in lieu of  $f_c, \epsilon_{cu}$

--->

Subcase: Rupture of tension steel

--->

$v^* < v^*s_y2$  - LHS eq.(4.5) is not satisfied

--->

$v^* < v^*s_{c,c}$  - LHS eq.(4.5) is not satisfied

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

$v^* < v^*c_y2$  - LHS eq.(4.6) is not satisfied

--->

$v^* < v^*c_y1$  - RHS eq.(4.6) is not satisfied

--->

$c_u$  (4.11) = 0.98280667

$M_{Ro}$  (4.18) = 1.3661E+008

$M_{Ro} < 0.8*M_{Rc}$

--->

$u = c_u$  (unconfined full section) = 1.6699237E-005

$\mu = M_{Rc}$

-----

Calculation of ratio  $I_b/I_d$

-----

Adequate Lap Length:  $I_b/I_d \geq 1$

-----

-----

-----

Calculation of Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 229892.529$

-----

Calculation of Shear Strength at edge 1,  $V_{r1} = 229892.529$

$V_{r1} = V_{CoI}$  ((10.3), ASCE 41-17) =  $k_n I * V_{CoI0}$

$V_{CoI0} = 229892.529$

$k_n = 1$  (zero step-static loading)

-----

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

-----

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

$f'_c = 18.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu = 1.2877E+008$

$V_u = 8.8389216E-005$

$d = 0.8*h = 360.00$

$N_u = 1.4060E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$

where:

$V_{s1} = 119678.523$  is calculated for section web, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$   
 $s = 210.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.58333333$   
 $V_{s2} = 0.00$  is calculated for section flange, with:  
 $d = 160.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 210.00$   
 $V_{s2}$  is multiplied by  $Col2 = 0.00$   
 $s/d = 1.3125$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$   
 $bw = 200.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 229892.529$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$   
 $V_{Col0} = 229892.529$   
 $knl = 1$  (zero step-static loading)

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

$= 1$  (normal-weight concrete)  
 $f_c' = 18.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 1.1237E+008$   
 $V_u = 8.8389216E-005$   
 $d = 0.8 * h = 360.00$   
 $N_u = 1.4060E+006$   
 $A_g = 90000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$   
 where:  
 $V_{s1} = 119678.523$  is calculated for section web, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 210.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.58333333$   
 $V_{s2} = 0.00$  is calculated for section flange, with:  
 $d = 160.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 210.00$   
 $V_{s2}$  is multiplied by  $Col2 = 0.00$   
 $s/d = 1.3125$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$   
 $bw = 200.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
 At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
 At Shear local axis: 2  
 (Bending local axis: 3)  
 Section Type: rccls

Constant Properties

Knowledge Factor,  $= 1.00$

Mean strength values are used for both shear and moment calculations.	
Consequently:	
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 18.00$	
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$	
Concrete Elasticity, $E_c = 19940.411$	
Steel Elasticity, $E_s = 200000.00$	
#####	
Note: Especially for the calculation of moment strengths,	
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14	
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$	
#####	
Max Height, $H_{max} = 450.00$	
Min Height, $H_{min} = 200.00$	
Max Width, $W_{max} = 450.00$	
Min Width, $W_{min} = 200.00$	
Cover Thickness, $c = 25.00$	
Mean Confinement Factor overall section = 1.00	
Element Length, $L = 3000.00$	
Secondary Member	
Smooth Bars	
Ductile Steel	
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)	
Longitudinal Bars With Ends Lapped Starting at the End Sections	
Adequate Lap Length ( $l_o/l_{ou,min} \geq 1$ )	
No FRP Wrapping	
-----	
Stepwise Properties	
-----	
At local axis: 2	
EDGE -A-	
Shear Force, $V_a = 3.7569140E-005$	
EDGE -B-	
Shear Force, $V_b = -3.7569140E-005$	
BOTH EDGES	
Axial Force, $F = -1.4060E+006$	
Longitudinal Reinforcement Area Distribution (in 2 divisions)	
-Tension: $As_t = 829.3805$	
-Compression: $As_c = 3091.327$	
Longitudinal Reinforcement Area Distribution (in 3 divisions)	
-Tension: $As_{t,ten} = 1746.726$	
-Compression: $As_{l,com} = 829.3805$	
-Middle: $As_{l,mid} = 1545.664$	
-----	
-----	
Calculation of Shear Capacity ratio , $V_e/V_r = 1.14637$	
Member Controlled by Shear ( $V_e/V_r > 1$ )	
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 263541.358$	
with	
$M_{pr1} = \text{Max}(\mu_{u1+} , \mu_{u1-}) = 3.9531E+008$	
$\mu_{u1+} = 2.8814E+008$ , 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	
$\mu_{u1-} = 3.9531E+008$ , 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	
$M_{pr2} = \text{Max}(\mu_{u2+} , \mu_{u2-}) = 3.9531E+008$	
$\mu_{u2+} = 2.8814E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction	
which is defined for the the static loading combination	
$\mu_{u2-} = 3.9531E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment	
direction which is defined for the the static loading combination	
-----	
Calculation of $\mu_{u1+}$	
-----	
-----	

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

$$\phi_u = 1.6699237E-005$$

$$\mu_u = 2.8814E+008$$

with full section properties:

$$b = 200.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$\nu = 0.95961609$$

$$N = 1.4060E+006$$

$$f_c = 18.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \rho_{cc}) = 0.00548378$$

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

$$\text{From (5.4b), TB DY: } \phi_u = 0.00548378$$

$$\phi_{ue} (5.4c) = 0.00245962$$

$$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00283171$$

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

$$\phi_{sh,x} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$\phi_{sh,y} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along X}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 18.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \rho_{cc} = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

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

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

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, TB DY.

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

$$\text{with } fs_1 = fs = 555.55$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

```

su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
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 = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.66229413
2 = Asl,com/(b*d)*(fs2/fc) = 0.31447059
v = Asl,mid/(b*d)*(fsv/fc) = 0.58605883
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.80684338
MRc (4.18) = 2.8814E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->

```

$v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied

--->

$v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

$v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied

--->

$v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied

--->

$*c_u$  (4.11) = 0.98280667

$M_{Ro}$  (4.18) = 1.3661E+008

$M_{Ro} < 0.8 * M_{Rc}$

--->

$u = c_u$  (unconfined full section) = 1.6699237E-005

$\mu_u = M_{Rc}$

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of  $\mu_{u1}$ -

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

$u = 1.0666733E-005$

$\mu_u = 3.9531E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.42649604$

$N = 1.4060E+006$

$f_c = 18.00$

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

Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.00548378$

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

From (5.4b), TBDY:  $c_u = 0.00548378$

$w_e$  (5.4c) = 0.00245962

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00283171$

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

$p_{sh,x}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along Y) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$$psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00283171$$

$$Lstir \text{ (Length of stirrups along X)} = 1060.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 140000.00$$

$$s = 210.00$$

$$fywe = 555.55$$

$$fce = 18.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

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

$$lo/lou,min = lb/ld = 1.00$$

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

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.

$$\text{with } fs1 = fs = 555.55$$

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

$$y2 = 0.00231479$$

$$sh2 = 0.008$$

$$ft2 = 666.66$$

$$fy2 = 555.55$$

$$su2 = 0.032$$

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

$$lo/lou,min = lb/lb,min = 1.00$$

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

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.

$$\text{with } fs2 = fs = 555.55$$

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

$$yv = 0.00231479$$

$$shv = 0.008$$

$$ftv = 666.66$$

$$fyv = 555.55$$

$$suv = 0.032$$

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

$$lo/lou,min = lb/ld = 1.00$$

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

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.

$$\text{with } fsv = fs = 555.55$$

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$fcc \text{ (5A.2, TBDY)} = 18.00$$



```

cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ec
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.4973444
MRo (4.18) = 3.9531E+008
---->
u = cu (4.2) = 1.0666733E-005
Mu = MRo
-----

Calculation of ratio lb/d
-----
Adequate Lap Length: lb/d >= 1
-----
-----

Calculation of Mu2+
-----
-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.6699237E-005
Mu = 2.8814E+008
-----

with full section properties:
b = 200.00
d = 407.00
d' = 43.00

```

$v = 0.95961609$   
 $N = 1.4060E+006$   
 $f_c = 18.00$   
 $\alpha (5A.5, TBDY) = 0.002$   
 Final value of  $\alpha$ :  $\alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.00548378$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\alpha = 0.00548378$   
 $\alpha_e (5.4c) = 0.00245962$   
 $\alpha_{se} = \text{Max}(((\alpha_{conf,max} - \alpha_{noConf}) / \alpha_{conf,max}) * (\alpha_{conf,min} / \alpha_{conf,max}), 0) = 0.09380979$   
 The definitions of  $\alpha_{noConf}$ ,  $\alpha_{conf,min}$  and  $\alpha_{conf,max}$  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.  
 $\alpha_{conf,max} = 89600.00$  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 perimeter hoops.  
 $\alpha_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $\alpha_{conf,max}$  by a length equal to half the clear spacing between hoops.  
 $\alpha_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $\alpha_{sh,min} = \text{Min}(\alpha_{sh,x}, \alpha_{sh,y}) = 0.00283171$   
 Expression ((5.4d), TBDY) for  $\alpha_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

---

$\alpha_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$   
 $L_{stir}$  (Length of stirrups along Y) = 1060.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 140000.00

---

$\alpha_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$   
 $L_{stir}$  (Length of stirrups along X) = 1060.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 140000.00

---

$s = 210.00$   
 $f_{ywe} = 555.55$   
 $f_{ce} = 18.00$   
 From ((5.A.5), TBDY), TBDY:  $\alpha_c = 0.002$   
 $\alpha_c$  = confinement factor = 1.00  
 $\gamma_1 = 0.00231479$   
 $\gamma_{sh1} = 0.008$   
 $f_{t1} = 666.66$   
 $f_{y1} = 555.55$   
 $\gamma_{su1} = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $\gamma_{lo/lo,min} = \gamma_{lb/l_d} = 1.00$   
 $\gamma_{su1} = 0.4 * \gamma_{su1\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $\gamma_{su1\_nominal} = 0.08$ ,  
 For calculation of  $\gamma_{su1\_nominal}$  and  $\gamma_1, \gamma_{sh1}, f_{t1}, f_{y1}$ , it is considered characteristic value  $f_{sy1} = f_{s1}/1.2$ , from table 5.1, TBDY.  
 $\gamma_1, \gamma_{sh1}, f_{t1}, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (\gamma_{lb/l_d})^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $f_{s1} = f_s = 555.55$   
 with  $E_{s1} = E_s = 200000.00$

$\gamma_2 = 0.00231479$   
 $\gamma_{sh2} = 0.008$   
 $f_{t2} = 666.66$   
 $f_{y2} = 555.55$   
 $\gamma_{su2} = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $\gamma_{lo/lo,min} = \gamma_{lb/l_b,min} = 1.00$   
 $\gamma_{su2} = 0.4 * \gamma_{su2\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $\gamma_{su2\_nominal} = 0.08$ ,  
 For calculation of  $\gamma_{su2\_nominal}$  and  $\gamma_2, \gamma_{sh2}, f_{t2}, f_{y2}$ , it is considered

```

characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.
with  $f_{s2} = f_s = 555.55$ 
with  $E_{s2} = E_s = 200000.00$ 
 $y_v = 0.00231479$ 
 $sh_v = 0.008$ 
 $ft_v = 666.66$ 
 $fy_v = 555.55$ 
 $suv = 0.032$ 
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 1.00$ 
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$ 
From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,
considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY
For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered
characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.
with  $f_{sv} = f_s = 555.55$ 
with  $E_{sv} = E_s = 200000.00$ 
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.66229413$ 
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.31447059$ 
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.58605883$ 
and confined core properties:
 $b = 140.00$ 
 $d = 377.00$ 
 $d' = 13.00$ 
 $f_{cc} (5A.2, TBDY) = 18.00$ 
 $cc (5A.5, TBDY) = 0.002$ 
 $c = \text{confinement factor} = 1.00$ 
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 1.02142$ 
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.48499254$ 
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.90384974$ 
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
 $v < v_{s,c}$  - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
 $v < s_{y1}$  - LHS eq.(4.7) is not satisfied
--->
 $v < v_{c,y1}$  - RHS eq.(4.6) is not satisfied
--->
 $cu (4.11) = 0.80684338$ 
 $M_{Rc} (4.18) = 2.8814E+008$ 
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
-  $b, d, d'$  replaced by geometric parameters of the core:  $b_o, d_o, d'_o$ 
-  $N, 1, 2, v$  normalised to  $b_o \cdot d_o$ , instead of  $b \cdot d$ 
-  $f_{cc}, cc$  parameters of confined concrete,  $f_{cc}, cc$ , used in lieu of  $f_c, cc_u$ 
--->
Subcase: Rupture of tension steel
--->
 $v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied
--->
 $v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->

```

$v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied

--->

$v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied

--->

\* $\mu_{cu}$  (4.11) = 0.98280667

$M_{Ro}$  (4.18) = 1.3661E+008

$M_{Ro} < 0.8 * M_{Rc}$

--->

$u = \mu_{cu}$  (unconfined full section) = 1.6699237E-005

$\mu_u = M_{Rc}$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

Calculation of  $\mu_{u2}$ -

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

$u = 1.0666733E-005$

$\mu_u = 3.9531E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.42649604$

$N = 1.4060E+006$

$f_c = 18.00$

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

Final value of  $\mu_{cu}$ :  $\mu_{cu}^* = \text{shear\_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.00548378$

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

From (5.4b), TBDY:  $\mu_{cu} = 0.00548378$

$\mu_{we}$  (5.4c) = 0.00245962

$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.00283171$

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

$\mu_{psh,x}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along Y) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$\mu_{psh,y}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along X) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$s = 210.00$

$f_{ywe} = 555.55$

$f_{ce} = 18.00$

From ((5.A.5), TBDY), TBDY:  $cc = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $y1 = 0.00231479$   
 $sh1 = 0.008$   
 $ft1 = 666.66$   
 $fy1 = 555.55$   
 $su1 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/ld = 1.00$   
 $su1 = 0.4 * esu1\_nominal ((5.5), TBDY) = 0.032$   
 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  $fs1 = fs = 555.55$   
 with  $Es1 = Es = 200000.00$   
 $y2 = 0.00231479$   
 $sh2 = 0.008$   
 $ft2 = 666.66$   
 $fy2 = 555.55$   
 $su2 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/lb, \min = 1.00$   
 $su2 = 0.4 * esu2\_nominal ((5.5), TBDY) = 0.032$   
 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  $fs2 = fs = 555.55$   
 with  $Es2 = Es = 200000.00$   
 $yv = 0.00231479$   
 $shv = 0.008$   
 $ftv = 666.66$   
 $fyv = 555.55$   
 $suv = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/ld = 1.00$   
 $suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$   
 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  $fsv = fs = 555.55$   
 with  $Esv = Es = 200000.00$   
 $1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.13976471$   
 $2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.29435295$   
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.26047059$   
 and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 18.00$   
 $cc (5A.5, TBDY) = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.17409989$   
 $2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.36666491$   
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.32445888$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' does not satisfy Eq. (4.3)

--->

$v < v_{s,c}$  - RHS eq.(4.5) is not satisfied

--->

Case/Assumption Rejected.

--->

New Case/Assumption: Unconfined full section - Spalling of concrete cover

' satisfies Eq. (4.4)

--->

$v < s_{y1}$  - LHS eq.(4.7) is not satisfied

--->

$v < v_{c,y1}$  - RHS eq.(4.6) is satisfied

--->

$\phi_{cu}$  (4.10) = 0.40653976

$M_{Rc}$  (4.17) = 4.7962E+008

--->

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- $b, d, d'$  replaced by geometric parameters of the core:  $b_o, d_o, d'_o$
- $N, \epsilon_1, \epsilon_2, \nu$  normalised to  $b_o*d_o$ , instead of  $b*d$
- $f_{cc}, \epsilon_{cc}$  parameters of confined concrete,  $f_{cc}, \epsilon_{cc}$  used in lieu of  $f_c, \epsilon_{cu}$

--->

Subcase: Rupture of tension steel

--->

$v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied

--->

$v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

$v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied

--->

$v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied

--->

$\phi^*_{cu}$  (4.11) = 0.4973444

$M_{Ro}$  (4.18) = 3.9531E+008

--->

$u = \phi_{cu}$  (4.2) = 1.0666733E-005

$M_u = M_{Ro}$

-----  
Calculation of ratio  $I_b/I_d$

-----  
Adequate Lap Length:  $I_b/I_d \geq 1$

-----  
Calculation of Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 229892.529$

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 229892.529$

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

$V_{ColO} = 229892.529$

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

-----  
NOTE: In expression (10-3) ' $V_s$ ' is replaced by ' $V_{s+} + f^*V_f$ '

where  $V_f$  is the contribution of FRPs ((11.3), ACI 440).

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

$f'_c = 18.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$M_u = 1.2440E+008$

$V_u = 3.7569140E-005$

$d = 0.8 * h = 360.00$

$N_u = 1.4060E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$

where:

$V_{s1} = 0.00$  is calculated for section web, with:

$$d = 160.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 210.00$$

$V_{s1}$  is multiplied by  $Col1 = 0.00$

$$s/d = 1.3125$$

$V_{s2} = 119678.523$  is calculated for section flange, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 210.00$$

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

$$s/d = 0.58333333$$

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

From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$

$$bw = 200.00$$

Calculation of Shear Strength at edge 2,  $V_{r2} = 229892.529$

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

$$V_{Col0} = 229892.529$$

$knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s$ ' is replaced by ' $V_s + f * V_f$ '

where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)

$f'_c = 18.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$\mu_u = 1.0841E+008$$

$$\nu_u = 3.7569140E-005$$

$$d = 0.8 * h = 360.00$$

$$N_u = 1.4060E+006$$

$$A_g = 90000.00$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$

where:

$V_{s1} = 0.00$  is calculated for section web, with:

$$d = 160.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 210.00$$

$V_{s1}$  is multiplied by  $Col1 = 0.00$

$$s/d = 1.3125$$

$V_{s2} = 119678.523$  is calculated for section flange, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 210.00$$

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

$$s/d = 0.58333333$$

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

From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$

$$bw = 200.00$$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rdcsls

## 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:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 18.00$

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

Concrete Elasticity,  $E_c = 19940.411$

Steel Elasticity,  $E_s = 200000.00$

Max Height,  $H_{max} = 450.00$

Min Height,  $H_{min} = 200.00$

Max Width,  $W_{max} = 450.00$

Min Width,  $W_{min} = 200.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_b/l_d > 1$ )

No FRP Wrapping

## Stepwise Properties

Bending Moment,  $M = 1.1240E+008$

Shear Force,  $V_2 = -33259.52$

Shear Force,  $V_3 = 2.78595$

Axial Force,  $F = -1.4054E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 829.3805$

-Compression:  $A_{sc} = 3292.389$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

-Compression:  $A_{st,com} = 1746.726$

-Middle:  $A_{st,mid} = 1545.664$

Mean Diameter of Tension Reinforcement,  $D_bL = 18.66667$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = u = 0.02547129$

$u = y + p = 0.02547129$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.02547129$  ((4.29), Biskinis Phd))

$M_y = 3.8889E+008$

$L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 6000.00

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 3.0536E+013$

factor = 0.70

$A_g = 140000.00$

$f_c' = 18.00$

$N = 1.4054E+006$

$E_c * I_g = 4.3623E+013$

Calculation of Yielding Moment  $M_y$

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

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



flange width, b = 450.00  
web width, bw = 200.00  
flange thickness, t = 200.00

y = Min( y\_ten, y\_com)  
y\_ten = 9.8162474E-006  
with fy = 444.44  
d = 407.00  
y = 0.44378431  
A = 0.03977101  
B = 0.02746764  
with pt = 0.00283171  
pc = 0.00953713  
pv = 0.00843933  
N = 1.4054E+006  
b = 450.00  
" = 0.10565111  
y\_comp = 8.6108073E-006  
with fc = 18.00  
Ec = 19940.411  
y = 0.46363116  
A = -0.00110899  
B = 0.01020151  
with Es = 200000.00  
CONFIRMATION: y = 0.46363116 < t/d

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

- Calculation of p -

From table 10-8: p = 0.00

with:

- Columns not controlled by inadequate development or splicing along the clear height because lb/d >= 1  
shear control ratio  $V_yE/V_{ColOE} = 1.14637$

d = 407.00

s = 150.00

$t = A_v/(b_w*s) + 2*tf/b_w*(ffe/fs) = A_v*Lstir/(Ag*s) + 2*tf/b_w*(ffe/fs) = 0.00283171$

$A_v = 78.53982$ , is the area of every stirrup

$Lstir = 1060.00$ , is the total Length of all stirrups parallel to loading (shear) direction

The term  $2*tf/b_w*(ffe/fs)$  is implemented to account for FRP contribution

where  $f = 2*tf/b_w$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $ffe/fs$  normalises f to steel strength

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

NUD = 1.4054E+006

Ag = 140000.00

fcE = 18.00

fytE = fytE = 444.44

$pl = Area\_Tot\_Long\_Rein/(b*d) = 0.02250488$

b = 450.00

d = 407.00

fcE = 18.00

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 7

column C1, Floor 1

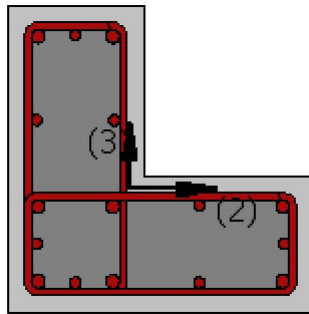
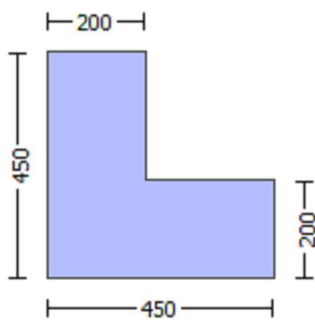
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rdcs

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:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 12.00$

Existing material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$

Concrete Elasticity,  $E_c = 19940.411$

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).

Existing material: Concrete Strength,  $f_c = f_{cm} = 18.00$

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

#####

Max Height,  $H_{max} = 450.00$

Min Height,  $H_{min} = 200.00$

Max Width,  $W_{max} = 450.00$

Min Width,  $W_{min} = 200.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections  
Adequate Lap Length ( $l_o/l_{o,u,min} = l_b/l_d \geq 1$ )  
No FRP Wrapping

#### Stepwise Properties

EDGE -A-  
Bending Moment,  $M_a = -1.5806E+008$   
Shear Force,  $V_a = -2.78595$   
EDGE -B-  
Bending Moment,  $M_b = 1.1240E+008$   
Shear Force,  $V_b = 2.78595$   
BOTH EDGES  
Axial Force,  $F = -1.4054E+006$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 829.3805$   
-Compression:  $A_{sc} = 3292.389$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten} = 829.3805$   
-Compression:  $A_{sc,com} = 1746.726$   
-Middle:  $A_{s,mid} = 1545.664$   
Mean Diameter of Tension Reinforcement,  $D_{bL,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = V_n = 206188.01$   
 $V_n ((10.3), ASCE 41-17) = k_n \cdot V_{CoI0} = 206188.01$   
 $V_{CoI} = 206188.01$   
 $k_n = 1.00$   
 $displacement\_ductility\_demand = 0.15618493$

NOTE: In expression (10-3) ' $V_s$ ' is replaced by ' $V_s + V_f$ '  
where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)  
 $f'_c = 12.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 1.1240E+008$   
 $V_u = 2.78595$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 1.4054E+006$   
 $A_g = 90000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 107711.748$   
where:  
 $V_{s1} = 107711.748$  is calculated for section web, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 210.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.58333333$   
 $V_{s2} = 0.00$  is calculated for section flange, with:  
 $d = 160.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 210.00$   
 $V_{s2}$  is multiplied by  $Col2 = 0.00$   
 $s/d = 1.3125$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
From (11-11), ACI 440:  $V_s + V_f \leq 165687.55$   
 $b_w = 200.00$

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

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

From analysis, chord rotation  $\theta = 0.00397823$   
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.02547129$  ((4.29), Biskinis Phd))  
 $M_y = 3.8889E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 6000.00  
From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 3.0536E+013$   
factor = 0.70  
 $A_g = 140000.00$   
 $f_c' = 18.00$   
 $N = 1.4054E+006$   
 $E_c \cdot I_g = 4.3623E+013$

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,  $b = 450.00$   
web width,  $b_w = 200.00$   
flange thickness,  $t = 200.00$

$y = \text{Min}(\phi_{y\_ten}, \phi_{y\_com})$   
 $\phi_{y\_ten} = 9.8162474E-006$   
with  $f_y = 444.44$   
 $d = 407.00$   
 $y = 0.44378431$   
 $A = 0.03977101$   
 $B = 0.02746764$   
with  $p_t = 0.00452842$   
 $p_c = 0.00953713$   
 $p_v = 0.00843933$   
 $N = 1.4054E+006$   
 $b = 450.00$   
 $" = 0.10565111$   
 $\phi_{y\_comp} = 8.6108073E-006$   
with  $f_c = 18.00$   
 $E_c = 19940.411$   
 $y = 0.46363116$   
 $A = -0.00110899$   
 $B = 0.01020151$   
with  $E_s = 200000.00$   
CONFIRMATION:  $y = 0.46363116 < t/d$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

## Calculation No. 8

column C1, Floor 1

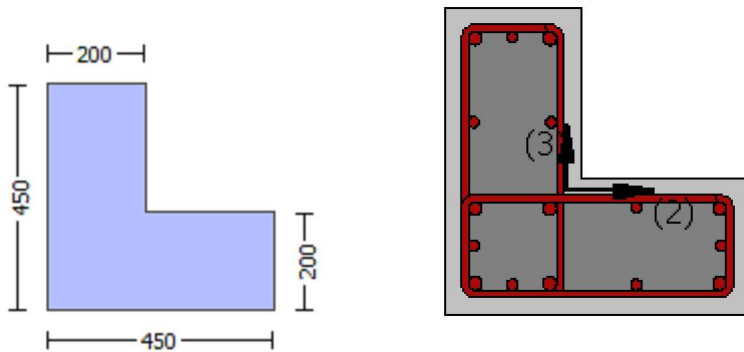
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\phi_r$ )

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rdcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 18.00$

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

Concrete Elasticity,  $E_c = 19940.411$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height,  $H_{max} = 450.00$

Min Height,  $H_{min} = 200.00$

Max Width,  $W_{max} = 450.00$

Min Width,  $W_{min} = 200.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_o/l_{ou,min} > 1$ )

## No FRP Wrapping

### Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = -8.8389216E-005$

EDGE -B-

Shear Force,  $V_b = 8.8389216E-005$

BOTH EDGES

Axial Force,  $F = -1.4060E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 829.3805$

-Compression:  $As_c = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

-Compression:  $As_{c,com} = 1746.726$

-Middle:  $As_{mid} = 1545.664$

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.14637$

Member Controlled by Shear ( $V_e/V_r > 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 263541.358$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 3.9531E+008$

$Mu_{1+} = 3.9531E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.8814E+008$ , 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 3.9531E+008$

$Mu_{2+} = 3.9531E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.8814E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

### Calculation of $Mu_{1+}$

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

$\phi_u = 1.0666733E-005$

$M_u = 3.9531E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.42649604$

$N = 1.4060E+006$

$f_c = 18.00$

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

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_0) = 0.00548378$

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

From (5.4b), TBDY:  $\phi_u = 0.00548378$

$\phi_{we}$  (5.4c) = 0.00245962

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.09380979$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

Aconf,min = 21600.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 54733.333 is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00283171

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

psh,x ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00283171

Lstir (Length of stirrups along Y) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00283171

Lstir (Length of stirrups along X) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

s = 210.00

fywe = 555.55

fce = 18.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

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

lo/lou,min = lb/lb,min = 1.00

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 = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
--->
v* < v*s,c - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
--->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
--->
*cu (4.11) = 0.4973444
MRo (4.18) = 3.9531E+008
--->
u = cu (4.2) = 1.0666733E-005
Mu = MRo

```

-----

Calculation of ratio lb/d

-----

Adequate Lap Length: lb/d >= 1

-----

-----



## Calculation of Mu1-

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

$$\mu = 1.6699237E-005$$

$$\mu_u = 2.8814E+008$$

with full section properties:

$$b = 200.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$\nu = 0.95961609$$

$$N = 1.4060E+006$$

$$f_c = 18.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, c_o) = 0.00548378$$

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

$$\text{From (5.4b), TB DY: } \mu_u = 0.00548378$$

$$\mu_{ue}(5.4c) = 0.00245962$$

$$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.00283171$$

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

$$\mu_{psh,x}((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$\mu_{psh,y}((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along X}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 18.00$$

$$\text{From ((5.A5), TB DY), TB DY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * su_{1,nominal}((5.5), \text{TB DY}) = 0.032$$

From table 5A.1, TB DY:  $su_{1,nominal} = 0.08$ ,

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

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

$$\text{with } fs_1 = fs = 555.55$$

```

    with Es1 = Es = 200000.00
    y2 = 0.00231479
    sh2 = 0.008
    ft2 = 666.66
    fy2 = 555.55
    su2 = 0.032
    using (30) in Biskinis/Fardis (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 = 1.00
    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 = 555.55
    with Es2 = Es = 200000.00
    yv = 0.00231479
    shv = 0.008
    ftv = 666.66
    fyv = 555.55
    suv = 0.032
    using (30) in Biskinis/Fardis (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 = 1.00
    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 = 555.55
    with Esv = Es = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.66229413
    2 = Asl,com/(b*d)*(fs2/fc) = 0.31447059
    v = Asl,mid/(b*d)*(fsv/fc) = 0.58605883
    and confined core properties:
    b = 140.00
    d = 377.00
    d' = 13.00
    fcc (5A.2, TBDY) = 18.00
    cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
    2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
    v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
    Case/Assumption: Unconfined full section - Steel rupture
    ' does not satisfy Eq. (4.3)
    --->
    v < vs,c - RHS eq.(4.5) is not satisfied
    --->
    Case/Assumption Rejected.
    --->
    New Case/Assumption: Unconfined full section - Spalling of concrete cover
    ' satisfies Eq. (4.4)
    --->
    v < sy1 - LHS eq.(4.7) is not satisfied
    --->
    v < vc,y1 - RHS eq.(4.6) is not satisfied
    --->
    cu (4.11) = 0.80684338
    MRc (4.18) = 2.8814E+008
    --->
    New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
    In expressions below, the following modifications have been made
    - b, d, d' replaced by geometric parameters of the core: bo, do, d'o

```

- $N_1, N_2$  v normalised to  $b_o \cdot d_o$ , instead of  $b \cdot d$
- parameters of confined concrete,  $f_{cc}$ ,  $\epsilon_{cc}$ , used in lieu of  $f_c$ ,  $\epsilon_{cu}$

---->

Subcase: Rupture of tension steel

---->

$v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied

---->

$v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied

---->

Subcase rejected

---->

New Subcase: Failure of compression zone

---->

$v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied

---->

$v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied

---->

$\epsilon_{cu} (4.11) = 0.98280667$

$M_{Ro} (4.18) = 1.3661E+008$

$M_{Ro} < 0.8 \cdot M_{Rc}$

---->

$\epsilon_u = \epsilon_{cu}$  (unconfined full section) =  $1.6699237E-005$

$\mu_u = M_{Rc}$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

Calculation of  $\mu_{u2+}$

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

$\epsilon_u = 1.0666733E-005$

$\mu_u = 3.9531E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.42649604$

$N = 1.4060E+006$

$f_c = 18.00$

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

Final value of  $\epsilon_{cu}$ :  $\epsilon_{cu}^* = \text{shear\_factor} \cdot \text{Max}(\epsilon_{cu}, \epsilon_{cc}) = 0.00548378$

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

From (5.4b), TBDY:  $\epsilon_{cu} = 0.00548378$

$\epsilon_{we} (5.4c) = 0.00245962$

$\epsilon_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\epsilon_{psh,min} = \text{Min}(\epsilon_{psh,x}, \epsilon_{psh,y}) = 0.00283171$

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

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00283171$$

$$Lstir \text{ (Length of stirrups along Y)} = 1060.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 140000.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00283171$$

$$Lstir \text{ (Length of stirrups along X)} = 1060.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 140000.00$$

$$s = 210.00$$

$$fywe = 555.55$$

$$fce = 18.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

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

$$lo/lou,min = lb/ld = 1.00$$

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

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.

$$\text{with } fs1 = fs = 555.55$$

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

$$y2 = 0.00231479$$

$$sh2 = 0.008$$

$$ft2 = 666.66$$

$$fy2 = 555.55$$

$$su2 = 0.032$$

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

$$lo/lou,min = lb/lb,min = 1.00$$

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

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.

$$\text{with } fs2 = fs = 555.55$$

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

$$yv = 0.00231479$$

$$shv = 0.008$$

$$ftv = 666.66$$

$$fyv = 555.55$$

$$suv = 0.032$$

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

$$lo/lou,min = lb/ld = 1.00$$

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

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.

$$\text{with } fsv = fs = 555.55$$

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.13976471$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.29435295$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.26047059$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 18.00$$

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

$$c = \text{confinement factor} = 1.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.17409989$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.36666491$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.32445888$$

Case/Assumption: Unconfined full section - Steel rupture

' does not satisfy Eq. (4.3)

---->

$v < v_{s,c}$  - RHS eq.(4.5) is not satisfied

---->

Case/Assumption Rejected.

---->

New Case/Assumption: Unconfined full section - Spalling of concrete cover

' satisfies Eq. (4.4)

---->

$v < s_{y1}$  - LHS eq.(4.7) is not satisfied

---->

$v < v_{c,y1}$  - RHS eq.(4.6) is satisfied

---->

$$\kappa_u (4.10) = 0.40653976$$

$$M_{Rc} (4.17) = 4.7962E+008$$

---->

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- $b, d, d'$  replaced by geometric parameters of the core:  $b_o, d_o, d'_o$
- $N_1, N_2, v$  normalised to  $b_o*d_o$ , instead of  $b*d$
- parameters of confined concrete,  $f_{cc}, \kappa_{cc}$ , used in lieu of  $f_c, \kappa_c$

---->

Subcase: Rupture of tension steel

---->

$v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied

---->

$v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied

---->

Subcase rejected

---->

New Subcase: Failure of compression zone

---->

$v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied

---->

$v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied

---->

$$\kappa^*_{cu} (4.11) = 0.4973444$$

$$M_{Ro} (4.18) = 3.9531E+008$$

---->

$$u = \kappa_{cu} (4.2) = 1.0666733E-005$$

$$\mu_u = M_{Ro}$$

Calculation of ratio  $l_b/d$

Adequate Lap Length:  $l_b/d \geq 1$

Calculation of  $\mu_{u2}$ -

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

$$u = 1.6699237E-005$$

$$\mu_u = 2.8814E+008$$

with full section properties:

$$b = 200.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.95961609$$

$$N = 1.4060E+006$$

$$f_c = 18.00$$

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

$$\text{Final value of } \alpha: \alpha = \text{shear\_factor} * \text{Max}(\alpha, \alpha) = 0.00548378$$

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

$$\text{From (5.4b), TB DY: } \alpha = 0.00548378$$

$$\alpha (5.4c) = 0.00245962$$

$$\alpha = \text{Max}(((\alpha_{\text{conf,max}} - \alpha_{\text{noConf}}) / \alpha_{\text{conf,max}}) * (\alpha_{\text{conf,min}} / \alpha_{\text{conf,max}}), 0) = 0.09380979$$

The definitions of  $\alpha_{\text{noConf}}$ ,  $\alpha_{\text{conf,min}}$  and  $\alpha_{\text{conf,max}}$  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.

$\alpha_{\text{conf,max}} = 89600.00$  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 perimeter hoops.

$\alpha_{\text{conf,min}} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $\alpha_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$\alpha_{\text{noConf}} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_{\text{sh,min}} = \text{Min}(\alpha_{\text{sh,x}}, \alpha_{\text{sh,y}}) = 0.00283171$$

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

$$\alpha_{\text{sh,x}} ((5.4d), \text{TB DY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00283171$$

$$L_{\text{stir}} (\text{Length of stirrups along Y}) = 1060.00$$

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

$$A_{\text{sec}} (\text{section area}) = 140000.00$$

$$\alpha_{\text{sh,y}} ((5.4d), \text{TB DY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00283171$$

$$L_{\text{stir}} (\text{Length of stirrups along X}) = 1060.00$$

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

$$A_{\text{sec}} (\text{section area}) = 140000.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 18.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \alpha = 0.002$$

$$\alpha = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

$$l_o/l_{o,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_1_{\text{nominal}} ((5.5), \text{TB DY}) = 0.032$$

$$\text{From table 5A.1, TB DY: } esu_1_{\text{nominal}} = 0.08,$$

For calculation of  $esu_1_{\text{nominal}}$  and  $y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TB DY.

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

$$\text{with } fs_1 = fs = 555.55$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

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

```

Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
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 = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.66229413
2 = Asl,com/(b*d)*(fs2/fc) = 0.31447059
v = Asl,mid/(b*d)*(fsv/fc) = 0.58605883
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is not satisfied
--->
cu (4.11) = 0.80684338
MRc (4.18) = 2.8814E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
--->
v* < v*s,c - LHS eq.(4.5) is not satisfied

```

```

--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
 $v^* < v^*c,y2$  - LHS eq.(4.6) is not satisfied
--->
 $v^* < v^*c,y1$  - RHS eq.(4.6) is not satisfied
--->
 $*cu(4.11) = 0.98280667$ 
 $MRO(4.18) = 1.3661E+008$ 
 $MRO < 0.8*MRc$ 
--->
 $u = cu$  (unconfined full section) =  $1.6699237E-005$ 
 $Mu = MRc$ 
-----

Calculation of ratio  $lb/ld$ 
-----
Adequate Lap Length:  $lb/ld \geq 1$ 
-----
-----
-----
Calculation of Shear Strength  $Vr = \text{Min}(Vr1,Vr2) = 229892.529$ 
-----
Calculation of Shear Strength at edge 1,  $Vr1 = 229892.529$ 
 $Vr1 = VCol$  ((10.3), ASCE 41-17) =  $knl*VColO$ 
 $VColO = 229892.529$ 
 $knl = 1$  (zero step-static loading)
-----
NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).
-----
= 1 (normal-weight concrete)
 $fc' = 18.00$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$ 
 $Mu = 1.2877E+008$ 
 $Vu = 8.8389216E-005$ 
 $d = 0.8*h = 360.00$ 
 $Nu = 1.4060E+006$ 
 $Ag = 90000.00$ 
From (11.5.4.8), ACI 318-14:  $Vs = Vs1 + Vs2 = 119678.523$ 
where:
 $Vs1 = 119678.523$  is calculated for section web, with:
 $d = 360.00$ 
 $Av = 157079.633$ 
 $fy = 444.44$ 
 $s = 210.00$ 
 $Vs1$  is multiplied by  $Col1 = 1.00$ 
 $s/d = 0.58333333$ 
 $Vs2 = 0.00$  is calculated for section flange, with:
 $d = 160.00$ 
 $Av = 157079.633$ 
 $fy = 444.44$ 
 $s = 210.00$ 
 $Vs2$  is multiplied by  $Col2 = 0.00$ 
 $s/d = 1.3125$ 
 $Vf$  ((11-3)-(11.4), ACI 440) =  $0.00$ 
From (11-11), ACI 440:  $Vs + Vf \leq 202924.977$ 
 $bw = 200.00$ 
-----
-----
Calculation of Shear Strength at edge 2,  $Vr2 = 229892.529$ 
 $Vr2 = VCol$  ((10.3), ASCE 41-17) =  $knl*VColO$ 
 $VColO = 229892.529$ 
 $knl = 1$  (zero step-static loading)

```



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

= 1 (normal-weight concrete)

$f_c' = 18.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.1237E+008$

$V_u = 8.8389216E-005$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.4060E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$

where:

$V_{s1} = 119678.523$  is calculated for section web, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$s/d = 0.58333333$

$V_{s2} = 0.00$  is calculated for section flange, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

$V_{s2}$  is multiplied by  $Col2 = 0.00$

$s/d = 1.3125$

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

From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$

$b_w = 200.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rccls

Constant Properties

Knowledge Factor,  $\phi = 1.00$

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

Consequently:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 18.00$

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

Concrete Elasticity,  $E_c = 19940.411$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height,  $H_{max} = 450.00$

Min Height,  $H_{min} = 200.00$

Max Width,  $W_{max} = 450.00$

Min Width,  $W_{min} = 200.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Adequate Lap Length ( $l_o/l_{ou,min} \geq 1$ )  
No FRP Wrapping

#### Stepwise Properties

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = 3.7569140E-005$   
EDGE -B-  
Shear Force,  $V_b = -3.7569140E-005$   
BOTH EDGES  
Axial Force,  $F = -1.4060E+006$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 829.3805$   
-Compression:  $As_c = 3091.327$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten} = 1746.726$   
-Compression:  $As_{c,com} = 829.3805$   
-Middle:  $As_{mid} = 1545.664$

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.14637$   
Member Controlled by Shear ( $V_e/V_r > 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 263541.358$   
with  
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 3.9531E+008$   
 $Mu_{1+} = 2.8814E+008$ , 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  
 $Mu_{1-} = 3.9531E+008$ , 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  
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 3.9531E+008$   
 $Mu_{2+} = 2.8814E+008$ , 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  
 $Mu_{2-} = 3.9531E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

#### Calculation of $Mu_{1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\phi_u = 1.6699237E-005$   
 $Mu = 2.8814E+008$

with full section properties:

$b = 200.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.95961609$   
 $N = 1.4060E+006$

$f_c = 18.00$

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

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_o) = 0.00548378$

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

From (5.4b), TBDY:  $\phi_u = 0.00548378$

$\phi_{we}$  (5.4c) = 0.00245962

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.09380979$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00283171$

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

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00283171$

$L_{stir}$  (Length of stirrups along Y) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00283171$

$L_{stir}$  (Length of stirrups along X) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$s = 210.00$

$f_{ywe} = 555.55$

$f_{ce} = 18.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.002$

$c = \text{confinement factor} = 1.00$

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

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

$l_o/l_{ou,min} = l_b/l_d = 1.00$

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

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

For calculation of  $esu1_{nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , 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  $fs_1 = fs = 555.55$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

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

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$

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

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

For calculation of  $esu2_{nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , 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  $fs_2 = fs = 555.55$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Aslten/(b*d)*(fs1/fc) = 0.66229413
2 = Aslcom/(b*d)*(fs2/fc) = 0.31447059
v = Aslmid/(b*d)*(fsv/fc) = 0.58605883
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Aslten/(b*d)*(fs1/fc) = 1.02142
2 = Aslcom/(b*d)*(fs2/fc) = 0.48499254
v = Aslmid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.80684338
MRc (4.18) = 2.8814E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.98280667
MRo (4.18) = 1.3661E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 1.6699237E-005
Mu = MRc
-----

```

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of  $\mu_{u1}$ -

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

$$\mu_u = 1.0666733E-005$$

$$\mu_u = 3.9531E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.42649604$$

$$N = 1.4060E+006$$

$$f_c = 18.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, c_o) = 0.00548378$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.00548378$$

$$\mu_{ue} \text{ (5.4c)} = 0.00245962$$

$$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.00283171$$

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

$$\mu_{psh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1060.00$$

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

$$A_{sec} \text{ (section area)} = 140000.00$$

$$\mu_{psh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1060.00$$

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

$$A_{sec} \text{ (section area)} = 140000.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 18.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

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

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  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs1 = fs = 555.55$   
with  $Es1 = Es = 200000.00$   
 $y2 = 0.00231479$   
 $sh2 = 0.008$   
 $ft2 = 666.66$   
 $fy2 = 555.55$   
 $su2 = 0.032$   
using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$   
and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou, min = lb/lb, min = 1.00$   
 $su2 = 0.4 \cdot esu2\_nominal ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs2 = fs = 555.55$   
with  $Es2 = Es = 200000.00$   
 $yv = 0.00231479$   
 $shv = 0.008$   
 $ftv = 666.66$   
 $fyv = 555.55$   
 $suv = 0.032$   
using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$   
and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou, min = lb/ld = 1.00$   
 $suv = 0.4 \cdot esuv\_nominal ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = fs = 555.55$   
with  $Esv = Es = 200000.00$   
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.13976471$   
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.29435295$   
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.26047059$   
and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 18.00$   
 $cc (5A.5, TBDY) = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.17409989$   
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.36666491$   
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.32445888$   
Case/Assumption: Unconfined full section - Steel rupture  
' does not satisfy Eq. (4.3)  
--->  
 $v < vs, c$  - RHS eq.(4.5) is not satisfied  
--->  
Case/Assumption Rejected.  
--->  
New Case/Assumption: Unconfined full section - Spalling of concrete cover  
' satisfies Eq. (4.4)  
--->  
 $v < s, y1$  - LHS eq.(4.7) is not satisfied  
--->  
 $v < vc, y1$  - RHS eq.(4.6) is satisfied  
--->  
 $cu (4.10) = 0.40653976$

MRC (4.17) = 4.7962E+008

---->

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N,  $\epsilon_s$ ,  $\epsilon_c$ ,  $\epsilon_{cs}$  normalised to  $\epsilon_{cs}$ , instead of  $\epsilon_s$
- $\epsilon_{cs}$  parameters of confined concrete,  $\epsilon_{cs}$ ,  $\epsilon_{cs}$ , used in lieu of  $\epsilon_c$ ,  $\epsilon_{cs}$

---->

Subcase: Rupture of tension steel

---->

$\epsilon_{cs}^* < \epsilon_{cs,y2}$  - LHS eq.(4.5) is not satisfied

---->

$\epsilon_{cs}^* < \epsilon_{cs,c}$  - LHS eq.(4.5) is not satisfied

---->

Subcase rejected

---->

New Subcase: Failure of compression zone

---->

$\epsilon_{cs}^* < \epsilon_{cs,y2}$  - LHS eq.(4.6) is not satisfied

---->

$\epsilon_{cs}^* < \epsilon_{cs,y1}$  - RHS eq.(4.6) is not satisfied

---->

$\epsilon_{cs}^*$  (4.11) = 0.4973444

MRO (4.18) = 3.9531E+008

---->

$\epsilon_{cs} = \epsilon_{cs}^*$  (4.2) = 1.0666733E-005

$\mu = MRO$

-----  
Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

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

-----  
Calculation of ultimate curvature  $\epsilon_{cs}^*$  according to 4.1, Biskinis/Fardis 2013:

$\epsilon_{cs} = 1.6699237E-005$

$\mu = 2.8814E+008$

-----  
with full section properties:

b = 200.00

d = 407.00

d' = 43.00

$\epsilon_{cs} = 0.95961609$

N = 1.4060E+006

$\epsilon_{cs} = 18.00$

$\epsilon_{cs}$  (5A.5, TBDY) = 0.002

Final value of  $\epsilon_{cs}^*$ :  $\epsilon_{cs}^* = \text{shear\_factor} * \text{Max}(\epsilon_{cs}, \epsilon_{cs}) = 0.00548378$

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

From (5.4b), TBDY:  $\epsilon_{cs} = 0.00548378$

$\epsilon_{cs}$  (5.4c) = 0.00245962

$\epsilon_{cs} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.09380979$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b^2/6$  as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00283171  
 Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

---


$$psh,x \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00283171$$

Lstir (Length of stirrups along Y) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

---


$$psh,y \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00283171$$

Lstir (Length of stirrups along X) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

---

s = 210.00

fywe = 555.55

fce = 18.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

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

Shear\_factor = 1.00

lo/lou,min = lb/lb = 1.00

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 = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

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

Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

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 = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

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

Shear\_factor = 1.00

lo/lou,min = lb/lb = 1.00

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 = 555.55



```

with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.66229413
2 = Asl,com/(b*d)*(fs2/fc) = 0.31447059
v = Asl,mid/(b*d)*(fsv/fc) = 0.58605883
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is not satisfied
--->
cu (4.11) = 0.80684338
MRc (4.18) = 2.8814E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
--->
v* < v*sc - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
--->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
--->
*cu (4.11) = 0.98280667
MRo (4.18) = 1.3661E+008
MRo < 0.8*MRc
--->
u = cu (unconfined full section) = 1.6699237E-005
Mu = MRc

```

-----

Calculation of ratio lb/d

-----

Adequate Lap Length: lb/d >= 1

-----

-----

-----

Calculation of Mu2-

-----

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

$$u = 1.0666733E-005$$

$$\mu = 3.9531E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.42649604$$

$$N = 1.4060E+006$$

$$f_c = 18.00$$

$$\phi_0 (5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00548378$$

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

$$\text{From (5.4b), TB DY: } \phi_u = 0.00548378$$

$$\phi_{ue} (5.4c) = 0.00245962$$

$$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00283171$$

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

$$\phi_{sh,x} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$\phi_{sh,y} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along X}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 18.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \phi_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

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

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

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, TB DY.

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

$$\text{with } fs_1 = fs = 555.55$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

```

ft2 = 666.66
fy2 = 555.55
su2 = 0.032
    using (30) in Biskinis/Fardis (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 = 1.00
    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 = 555.55
    with Es2 = Es = 200000.00
    yv = 0.00231479
    shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (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 = 1.00
    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 = 555.55
    with Esv = Es = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
    2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
    v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
    2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
    v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->

```

Subcase: Rupture of tension steel

--->

$v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied

--->

$v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

$v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied

--->

$v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied

--->

$*c_u(4.11) = 0.4973444$

$M_{Ro}(4.18) = 3.9531E+008$

--->

$u = c_u(4.2) = 1.0666733E-005$

$\mu = M_{Ro}$

Calculation of ratio  $l_b/d$

Adequate Lap Length:  $l_b/d \geq 1$

Calculation of Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 229892.529$

Calculation of Shear Strength at edge 1,  $V_{r1} = 229892.529$

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

$V_{Col0} = 229892.529$

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

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

$= 1$  (normal-weight concrete)

$f'_c = 18.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.2440E+008$

$V_u = 3.7569140E-005$

$d = 0.8 * h = 360.00$

$N_u = 1.4060E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$

where:

$V_{s1} = 0.00$  is calculated for section web, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

$V_{s1}$  is multiplied by  $Col1 = 0.00$

$s/d = 1.3125$

$V_{s2} = 119678.523$  is calculated for section flange, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

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

$s/d = 0.58333333$

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

From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$

$b_w = 200.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 229892.529$

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

$V_{Col0} = 229892.529$

$knl = 1$  (zero step-static loading)

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

$= 1$  (normal-weight concrete)

$f'_c = 18.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.0841E+008$

$V_u = 3.7569140E-005$

$d = 0.8 * h = 360.00$

$N_u = 1.4060E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$

where:

$V_{s1} = 0.00$  is calculated for section web, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

$V_{s1}$  is multiplied by  $Col1 = 0.00$

$s/d = 1.3125$

$V_{s2} = 119678.523$  is calculated for section flange, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

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

$s/d = 0.58333333$

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

From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$

$bw = 200.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rdcs

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:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 18.00$

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

Concrete Elasticity,  $E_c = 19940.411$

Steel Elasticity,  $E_s = 200000.00$

Max Height,  $H_{max} = 450.00$

Min Height,  $H_{min} = 200.00$

Max Width,  $W_{max} = 450.00$

Min Width,  $W_{min} = 200.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Adequate Lap Length ( $l_b/l_d \geq 1$ )  
No FRP Wrapping

#### Stepwise Properties

Bending Moment,  $M = 1.1506 \times 10^8$   
Shear Force,  $V_2 = -33259.52$   
Shear Force,  $V_3 = 2.78595$   
Axial Force,  $F = -1.4054 \times 10^6$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 829.3805$   
-Compression:  $A_{sc} = 3292.389$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten} = 1746.726$   
-Compression:  $A_{sc,com} = 829.3805$   
-Middle:  $A_{st,mid} = 1545.664$   
Mean Diameter of Tension Reinforcement,  $D_{bL} = 17.71429$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $\phi_{u,R} = \phi_u = 0.00762341$   
 $\phi_u = \phi_y + \phi_p = 0.00762341$

- Calculation of  $\phi_y$  -

$\phi_y = (M_y \cdot L_s / 3) / E_{eff} = 0.00762341$  ((4.29), Biskinis Phd))  
 $M_y = 2.0187 \times 10^8$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 3459.388  
From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 3.0536 \times 10^{13}$   
factor = 0.70  
 $A_g = 140000.00$   
 $f_c' = 18.00$   
 $N = 1.4054 \times 10^6$   
 $E_c \cdot I_g = 4.3623 \times 10^{13}$

#### Calculation of Yielding Moment $M_y$

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

$\phi_y = \min(\phi_{y,ten}, \phi_{y,com})$   
 $\phi_{y,ten} = 1.3705819 \times 10^{-5}$   
with  $f_y = 444.44$   
 $d = 407.00$   
 $\phi_y = 0.60163265$   
 $A = 0.08948478$   
 $B = 0.07188114$   
with  $p_t = 0.00283171$   
 $p_c = 0.01018895$   
 $p_v = 0.0189885$   
 $N = 1.4054 \times 10^6$   
 $b = 200.00$   
 $\phi_y = 0.10565111$   
 $\phi_{y,comp} = 4.7559098 \times 10^{-6}$   
with  $f_c' = 18.00$   
 $E_c = 19940.411$   
 $\phi_y = 0.8394269$   
 $A = -0.00249523$   
 $B = 0.03303234$   
with  $E_s = 200000.00$

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

- Calculation of  $p$  -

From table 10-8:  $p = 0.00$

with:

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

shear control ratio  $V_y E/V_{Co} E = 1.14637$

$d = 407.00$

$s = 150.00$

$t = A_v/(b_w s) + 2 t_f/b_w (f_{fe}/f_s) = A_v L_{stir}/(A_g s) + 2 t_f/b_w (f_{fe}/f_s) = 0.00283171$

$A_v = 78.53982$ , is the area of every stirrup

$L_{stir} = 1060.00$ , is the total Length of all stirrups parallel to loading (shear) direction

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

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

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

$NUD = 1.4054E+006$

$A_g = 140000.00$

$f_{cE} = 18.00$

$f_{tE} = f_{yE} = 444.44$

$p_l = \text{Area\_Tot\_Long\_Rein}/(b d) = 0.05063599$

$b = 200.00$

$d = 407.00$

$f_{cE} = 18.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

## Calculation No. 9

column C1, Floor 1

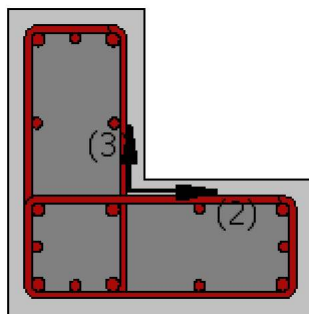
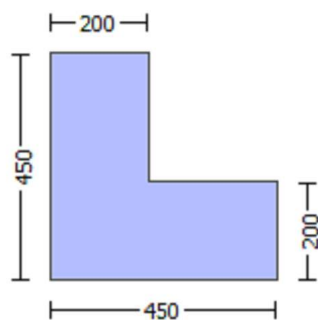
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcls

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:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 12.00$

Existing material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$

Concrete Elasticity,  $E_c = 19940.411$

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).

Existing material: Concrete Strength,  $f_c = f_{cm} = 18.00$

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

#####

Max Height,  $H_{max} = 450.00$

Min Height,  $H_{min} = 200.00$

Max Width,  $W_{max} = 450.00$

Min Width,  $W_{min} = 200.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_o/l_{ou,min} = l_b/l_d \geq 1$ )

No FRP Wrapping

Stepwise Properties

EDGE -A-

Bending Moment,  $M_a = -1.2613E+008$

Shear Force,  $V_a = 87433.392$

EDGE -B-

Bending Moment,  $M_b = 1.2593E+008$

Shear Force,  $V_b = -87433.392$

BOTH EDGES

Axial Force,  $F = -1.4055E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 1545.664$

-Compression:  $As_c = 2576.106$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 1746.726$



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

-Middle:  $A_{sl,mid} = 1545.664$

Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = V_n = 144333.043$

$V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{CoIO} = 144333.043$

$V_{CoI} = 206190.061$

$k_n = 0.70$

displacement\_ductility\_demand = 19.59614

NOTE: In expression (10-3) ' $V_s$ ' is replaced by ' $V_s + f \cdot V_f$ '

where  $V_f$  is the contribution of FRPs ((11.3), ACI 440).

= 1 (normal-weight concrete)

$f_c' = 12.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$M_u = 1.2613E+008$

$V_u = 87433.392$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.4055E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 107711.748$

where:

$V_{s1} = 0.00$  is calculated for section web, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 210.00$

$V_{s1}$  is multiplied by  $Col1 = 0.00$

$s/d = 1.3125$

$V_{s2} = 107711.748$  is calculated for section flange, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 210.00$

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

$s/d = 0.58333333$

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

From (11-11), ACI 440:  $V_s + V_f \leq 165687.55$

$b_w = 200.00$

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

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

From analysis, chord rotation  $\phi = 0.06229582$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00317898$  ((4.29), Biskinis Phd))

$M_y = 2.0187E+008$

$L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 1442.605

From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 3.0536E+013$

factor = 0.70

$A_g = 140000.00$

$f_c' = 18.00$

$N = 1.4055E+006$

$E_c \cdot I_g = 4.3623E+013$

Calculation of Yielding Moment  $M_y$

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

```

y = Min( y_ten, y_com)
y_ten = 1.3705984E-005
with fy = 444.44
d = 407.00
y = 0.60163744
A = 0.08948658
B = 0.07188293
with pt = 0.02145854
pc = 0.01018895
pv = 0.0189885
N = 1.4055E+006
b = 200.00
" = 0.10565111
y_comp = 4.7557658E-006
with fc = 18.00
Ec = 19940.411
y = 0.83945231
A = -0.00249769
B = 0.03303234
with Es = 200000.00

```

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (a)

## Calculation No. 10

column C1, Floor 1

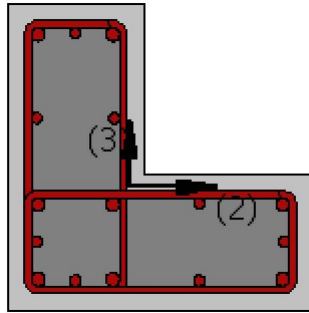
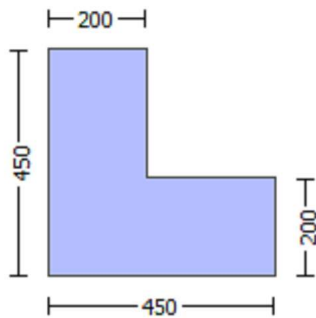
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\theta$  )

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rccls

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 18.00$

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

Concrete Elasticity,  $E_c = 19940.411$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height,  $H_{max} = 450.00$

Min Height,  $H_{min} = 200.00$

Max Width,  $W_{max} = 450.00$

Min Width,  $W_{min} = 200.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_o/l_{ou, min} > 1$ )

No FRP Wrapping

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = -8.8389216E-005$

EDGE -B-

Shear Force,  $V_b = 8.8389216E-005$

BOTH EDGES

Axial Force,  $F = -1.4060E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 829.3805$

-Compression:  $As_c = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

-Compression:  $As_{c, com} = 1746.726$

-Middle:  $As_{l, mid} = 1545.664$

Calculation of Shear Capacity ratio ,  $V_e/V_r = 1.14637$

Member Controlled by Shear ( $V_e/V_r > 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 263541.358$   
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 3.9531\text{E}+008$

$\mu_{1+} = 3.9531\text{E}+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{1-} = 2.8814\text{E}+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 3.9531\text{E}+008$

$\mu_{2+} = 3.9531\text{E}+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 2.8814\text{E}+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $\mu_{1+}$

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

$\mu = 1.0666733\text{E}-005$

$M_u = 3.9531\text{E}+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.42649604$

$N = 1.4060\text{E}+006$

$f_c = 18.00$

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

Final value of  $\phi_{cu}$ :  $\phi_{cu}^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_c) = 0.00548378$

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

From (5.4b), TBDY:  $\phi_{cu} = 0.00548378$

$\phi_{we}$  (5.4c) = 0.00245962

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.09380979$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and

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

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\phi_{psh,min} = \text{Min}(\phi_{psh,x}, \phi_{psh,y}) = 0.00283171$

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

$\phi_{psh,x}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along Y) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$\phi_{psh,y}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along X) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$s = 210.00$

$f_{ywe} = 555.55$

```

fce = 18.00
From ((5A.5), TBDY), TBDY: cc = 0.002
c = confinement factor = 1.00
y1 = 0.00231479
sh1 = 0.008
ft1 = 666.66
fy1 = 555.55
su1 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
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 = 555.55
with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
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 = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)

```

```

---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
'satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N1, N2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.4973444
MRo (4.18) = 3.9531E+008
---->
u = cu (4.2) = 1.0666733E-005
Mu = MRo

```

-----

Calculation of ratio lb/d

-----

Adequate Lap Length: lb/d >= 1

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-----

-----

Calculation of Mu1-

-----

-----

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

u = 1.6699237E-005  
Mu = 2.8814E+008

-----

with full section properties:

b = 200.00  
d = 407.00  
d' = 43.00  
v = 0.95961609  
N = 1.4060E+006  
f<sub>c</sub> = 18.00  
c<sub>o</sub> (5A.5, TBDY) = 0.002  
Final value of cu: cu\* = shear\_factor \* Max( cu, c<sub>c</sub>) = 0.00548378  
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY: cu = 0.00548378

$$w_e (5.4c) = 0.00245962$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$$

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.

$A_{conf,max}$  = 89600.00 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 perimeter hoops.

$A_{conf,min}$  = 21600.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf}$  = 54733.333 is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00283171$$

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

$$p_{sh,x} ((5.4d), \text{TBDY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$p_{sh,y} ((5.4d), \text{TBDY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along X}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 18.00$$

$$\text{From } ((5.A5), \text{TBDY}), \text{TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

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

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.

$$\text{with } fs_1 = fs = 555.55$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

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

$$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$$

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

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

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

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

$$\text{with } fs_2 = fs = 555.55$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

```

fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (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 = 1.00
    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 = 555.55
    with Esv = Es = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.66229413
    2 = Asl,com/(b*d)*(fs2/fc) = 0.31447059
    v = Asl,mid/(b*d)*(fsv/fc) = 0.58605883
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
    2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
    v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
    cu (4.11) = 0.80684338
    MRc (4.18) = 2.8814E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
    - b, d, d' replaced by geometric parameters of the core: bo, do, d'o
    - N, 1, 2, v normalised to bo*do, instead of b*d
    - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
    *cu (4.11) = 0.98280667
    MRo (4.18) = 1.3661E+008
    MRo < 0.8*MRc

```



--->

u = cu (unconfined full section) = 1.6699237E-005  
Mu = MRc

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

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

u = 1.0666733E-005  
Mu = 3.9531E+008

with full section properties:

b = 450.00  
d = 407.00  
d' = 43.00  
v = 0.42649604  
N = 1.4060E+006

fc = 18.00  
co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.00548378

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

From (5.4b), TBDY: cu = 0.00548378

we (5.4c) = 0.00245962

ase = Max(((Aconf,max-AnoConf)/Aconf,max)\*(Aconf,min/Aconf,max),0) = 0.09380979

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,max = 89600.00 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 perimeter hoops.

Aconf,min = 21600.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 54733.333 is the unconfined core area which is equal to bi2/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00283171

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

psh,x ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00283171

Lstir (Length of stirrups along Y) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00283171

Lstir (Length of stirrups along X) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

s = 210.00

fywe = 555.55

fce = 18.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

```

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.
with fs1 = fs = 555.55
with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
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 = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->

```

$v < s, y1$  - LHS eq.(4.7) is not satisfied  
 --->  
 $v < v_c, y1$  - RHS eq.(4.6) is satisfied  
 --->  
 $\epsilon_{cu}$  (4.10) = 0.40653976  
 $M_{Rc}$  (4.17) = 4.7962E+008  
 --->

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover  
 In expressions below, the following modifications have been made

- $b, d, d'$  replaced by geometric parameters of the core:  $b_o, d_o, d'_o$
- $N, 1, 2, v$  normalised to  $b_o * d_o$ , instead of  $b * d$
- parameters of confined concrete,  $f_{cc}, \epsilon_{cc}$ , used in lieu of  $f_c, \epsilon_{cu}$

Subcase: Rupture of tension steel

$v^* < v^* s, y2$  - LHS eq.(4.5) is not satisfied  
 --->

$v^* < v^* s, c$  - LHS eq.(4.5) is not satisfied  
 --->

Subcase rejected

New Subcase: Failure of compression zone

$v^* < v^* c, y2$  - LHS eq.(4.6) is not satisfied  
 --->

$v^* < v^* c, y1$  - RHS eq.(4.6) is not satisfied  
 --->

$\epsilon^*_{cu}$  (4.11) = 0.4973444  
 $M_{Ro}$  (4.18) = 3.9531E+008  
 --->

$u = \epsilon_{cu}$  (4.2) = 1.0666733E-005  
 $M_u = M_{Ro}$

Calculation of ratio  $l_b/d$

Adequate Lap Length:  $l_b/d \geq 1$

Calculation of  $M_{u2}$

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

$u = 1.6699237E-005$   
 $M_u = 2.8814E+008$

with full section properties:

$b = 200.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.95961609$   
 $N = 1.4060E+006$   
 $f_c = 18.00$   
 $\epsilon_{co}$  (5A.5, TBDY) = 0.002  
 Final value of  $\epsilon_{cu}$ :  $\epsilon_{cu}^* = \text{shear\_factor} * \text{Max}(\epsilon_{cu}, \epsilon_{cc}) = 0.00548378$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\epsilon_{cu} = 0.00548378$   
 $\epsilon_{we}$  (5.4c) = 0.00245962  
 $\epsilon_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$   
 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.  
 $A_{conf,max} = 89600.00$  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 perimeter hoops.  
 $A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and  
 is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length  
 equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh,min = \text{Min}(psh,x, psh,y) = 0.00283171$

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

$psh,x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along Y) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$psh,y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along X) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$s = 210.00$

$f_{ywe} = 555.55$

$f_{ce} = 18.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.002$

$c = \text{confinement factor} = 1.00$

$y1 = 0.00231479$

$sh1 = 0.008$

$ft1 = 666.66$

$fy1 = 555.55$

$su1 = 0.032$

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

$l_o/l_{ou,min} = l_b/l_d = 1.00$

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

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.

with  $fs1 = fs = 555.55$

with  $Es1 = Es = 200000.00$

$y2 = 0.00231479$

$sh2 = 0.008$

$ft2 = 666.66$

$fy2 = 555.55$

$su2 = 0.032$

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

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$

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

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

For calculation of  $esu2_{nominal}$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

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

with  $fs2 = fs = 555.55$

with  $Es2 = Es = 200000.00$

$yv = 0.00231479$

$shv = 0.008$

$ftv = 666.66$

$fyv = 555.55$

$suv = 0.032$

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

$l_o/l_{ou,min} = l_b/l_d = 1.00$

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

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

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY  
For calculation of  $e_{suv\_nominal}$  and  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $f_{yv}$ , it is considered  
characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1$ ,  $ft_1$ ,  $f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $f_{sv} = f_s = 555.55$   
with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.66229413$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.31447059$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.58605883$   
and confined core properties:  
 $b = 140.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} \text{ (5A.2, TBDY)} = 18.00$   
 $cc \text{ (5A.5, TBDY)} = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 1.02142$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.48499254$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.90384974$   
Case/Assumption: Unconfined full section - Steel rupture  
' does not satisfy Eq. (4.3)  
--->  
 $v < v_{s,c}$  - RHS eq.(4.5) is not satisfied  
--->  
Case/Assumption Rejected.  
--->  
New Case/Assumption: Unconfined full section - Spalling of concrete cover  
' satisfies Eq. (4.4)  
--->  
 $v < s_{y1}$  - LHS eq.(4.7) is not satisfied  
--->  
 $v < v_{c,y1}$  - RHS eq.(4.6) is not satisfied  
--->  
 $cu \text{ (4.11)} = 0.80684338$   
 $M_{Rc} \text{ (4.18)} = 2.8814E+008$   
--->  
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover  
In expressions below, the following modifications have been made  
-  $b$ ,  $d$ ,  $d'$  replaced by geometric parameters of the core:  $b_o$ ,  $d_o$ ,  $d'_o$   
-  $N$ ,  $1$ ,  $2$ ,  $v$  normalised to  $b_o \cdot d_o$ , instead of  $b \cdot d$   
-  $f_{cc}$ ,  $cc$ , used in lieu of  $f_c$ ,  $ecu$   
--->  
Subcase: Rupture of tension steel  
--->  
 $v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied  
--->  
 $v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied  
--->  
Subcase rejected  
--->  
New Subcase: Failure of compression zone  
--->  
 $v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied  
--->  
 $v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied  
--->  
 $*cu \text{ (4.11)} = 0.98280667$   
 $M_{Ro} \text{ (4.18)} = 1.3661E+008$   
 $M_{Ro} < 0.8 \cdot M_{Rc}$   
--->  
 $u = cu \text{ (unconfined full section)} = 1.6699237E-005$   
 $Mu = M_{Rc}$

---

Calculation of ratio  $l_b/l_d$

---

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 229892.529$

Calculation of Shear Strength at edge 1,  $V_{r1} = 229892.529$

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

$V_{\text{ColO}} = 229892.529$

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

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

$= 1$  (normal-weight concrete)

$f'_c = 18.00$ , but  $f'_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.2877\text{E}+008$

$V_u = 8.8389216\text{E}-005$

$d = 0.8 * h = 360.00$

$N_u = 1.4060\text{E}+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$

where:

$V_{s1} = 119678.523$  is calculated for section web, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

$V_{s1}$  is multiplied by  $\text{Col1} = 1.00$

$s/d = 0.58333333$

$V_{s2} = 0.00$  is calculated for section flange, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

$V_{s2}$  is multiplied by  $\text{Col2} = 0.00$

$s/d = 1.3125$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 0.00$

From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$

$b_w = 200.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 229892.529$

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

$V_{\text{ColO}} = 229892.529$

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

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

$= 1$  (normal-weight concrete)

$f'_c = 18.00$ , but  $f'_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.1237\text{E}+008$

$V_u = 8.8389216\text{E}-005$

$d = 0.8 * h = 360.00$

$N_u = 1.4060\text{E}+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$

where:

$V_{s1} = 119678.523$  is calculated for section web, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

$V_{s1}$  is multiplied by  $\text{Col1} = 1.00$

```

s/d = 0.58333333
Vs2 = 0.00 is calculated for section flange, with:
d = 160.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs2 is multiplied by Col2 = 0.00
s/d = 1.3125
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 202924.977
bw = 200.00
-----

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At local axis: 3
-----

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rdcs

Constant Properties
-----
Knowledge Factor, = 1.00
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Secondary Member: Concrete Strength, fc = fcm = 18.00
Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44
Concrete Elasticity, Ec = 19940.411
Steel Elasticity, Es = 200000.00
#####
Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, fs = 1.25*fsm = 555.55
#####
Max Height, Hmax = 450.00
Min Height, Hmin = 200.00
Max Width, Wmax = 450.00
Min Width, Wmin = 200.00
Cover Thickness, c = 25.00
Mean Confinement Factor overall section = 1.00
Element Length, L = 3000.00
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length (lo/lou, min>= 1)
No FRP Wrapping
-----

Stepwise Properties
-----
At local axis: 2
EDGE -A-
Shear Force, Va = 3.7569140E-005
EDGE -B-
Shear Force, Vb = -3.7569140E-005
BOTH EDGES
Axial Force, F = -1.4060E+006
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 829.3805
-Compression: Aslc = 3091.327
Longitudinal Reinforcement Area Distribution (in 3 divisions)

```

-Tension:  $A_{sl,ten} = 1746.726$   
 -Compression:  $A_{sl,com} = 829.3805$   
 -Middle:  $A_{sl,mid} = 1545.664$

Calculation of Shear Capacity ratio ,  $V_e/V_r = 1.14637$

Member Controlled by Shear ( $V_e/V_r > 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 263541.358$   
 with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 3.9531E+008$

$M_{u1+} = 2.8814E+008$ , 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

$M_{u1-} = 3.9531E+008$ , 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 3.9531E+008$

$M_{u2+} = 2.8814E+008$ , 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

$M_{u2-} = 3.9531E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $M_{u1+}$

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

$\phi_u = 1.6699237E-005$

$M_u = 2.8814E+008$

with full section properties:

$b = 200.00$

$d = 407.00$

$d' = 43.00$

$v = 0.95961609$

$N = 1.4060E+006$

$f_c = 18.00$

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

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00548378$

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

From (5.4b), TBDY:  $\phi_u = 0.00548378$

$\phi_{ue}$  (5.4c) = 0.00245962

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.09380979$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\phi_{psh,min} = \text{Min}(\phi_{psh,x}, \phi_{psh,y}) = 0.00283171$

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

$\phi_{psh,x}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along Y) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$\phi_{psh,y}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along X) = 1060.00

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



Asec (section area) = 140000.00

s = 210.00

fywe = 555.55

fce = 18.00

From ((5.A.5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

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

lo/lou,min = lb/lb = 1.00

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 = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

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

lo/lou,min = lb/lb,min = 1.00

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 = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

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

lo/lou,min = lb/lb = 1.00

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 = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.66229413

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.31447059

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.58605883

and confined core properties:

b = 140.00

d = 377.00

d' = 13.00

fcc (5A.2, TBDY) = 18.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 1.02142

```

2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.80684338
MRc (4.18) = 2.8814E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.98280667
MRo (4.18) = 1.3661E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 1.6699237E-005
Mu = MRc
-----

Calculation of ratio lb/ld
-----
Adequate Lap Length: lb/ld >= 1
-----

Calculation of Mu1-
-----

-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.0666733E-005
Mu = 3.9531E+008
-----

with full section properties:
b = 450.00
d = 407.00
d' = 43.00
v = 0.42649604
N = 1.4060E+006

```

$f_c = 18.00$   
 $\alpha (5A.5, \text{TB DY}) = 0.002$   
 Final value of  $\alpha$ :  $\alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.00548378$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TB DY:  $\alpha = 0.00548378$   
 $\alpha_e (5.4c) = 0.00245962$   
 $\alpha_{se} = \text{Max}(((\alpha_{conf,max} - \alpha_{noConf}) / \alpha_{conf,max}) * (\alpha_{conf,min} / \alpha_{conf,max}), 0) = 0.09380979$   
 The definitions of  $\alpha_{noConf}$ ,  $\alpha_{conf,min}$  and  $\alpha_{conf,max}$  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.  
 $\alpha_{conf,max} = 89600.00$  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 perimeter hoops.  
 $\alpha_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $\alpha_{conf,max}$  by a length equal to half the clear spacing between hoops.  
 $\alpha_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $\alpha_{sh,min} = \text{Min}(\alpha_{sh,x}, \alpha_{sh,y}) = 0.00283171$   
 Expression ((5.4d), TB DY) for  $\alpha_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\alpha_{sh,x} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$   
 $L_{stir}$  (Length of stirrups along Y) = 1060.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 140000.00

$\alpha_{sh,y} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$   
 $L_{stir}$  (Length of stirrups along X) = 1060.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 140000.00

$s = 210.00$   
 $f_{ywe} = 555.55$   
 $f_{ce} = 18.00$

From ((5.A5), TB DY), TB DY:  $\alpha_c = 0.002$   
 $\alpha_c$  = confinement factor = 1.00

$y_1 = 0.00231479$   
 $sh_1 = 0.008$   
 $ft_1 = 666.66$   
 $fy_1 = 555.55$   
 $su_1 = 0.032$

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

$su_1 = 0.4 * \alpha_{su1\_nominal} ((5.5), \text{TB DY}) = 0.032$

From table 5A.1, TB DY:  $\alpha_{su1\_nominal} = 0.08$ ,

For calculation of  $\alpha_{su1\_nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = f_s/1.2$ , from table 5.1, TB DY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_1 = f_s = 555.55$   
 with  $E_{s1} = E_s = 200000.00$

$y_2 = 0.00231479$   
 $sh_2 = 0.008$   
 $ft_2 = 666.66$   
 $fy_2 = 555.55$   
 $su_2 = 0.032$

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

$su_2 = 0.4 * \alpha_{su2\_nominal} ((5.5), \text{TB DY}) = 0.032$

From table 5A.1, TB DY:  $\alpha_{su2\_nominal} = 0.08$ ,

For calculation of  $\alpha_{su2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $fsy_2 = f_s/1.2$ , from table 5.1, TB DY.

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

```

with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < s,y1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
--->
v* < v*s,c - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
--->

```

$v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied

--->

$$*cu(4.11) = 0.4973444$$

$$MRo(4.18) = 3.9531E+008$$

--->

$$u = cu(4.2) = 1.0666733E-005$$

$$Mu = MRo$$

Calculation of ratio  $lb/ld$

Adequate Lap Length:  $lb/ld \geq 1$

Calculation of  $Mu_{2+}$

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

$$u = 1.6699237E-005$$

$$Mu = 2.8814E+008$$

with full section properties:

$$b = 200.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.95961609$$

$$N = 1.4060E+006$$

$$fc = 18.00$$

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

$$\text{Final value of } cu: cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00548378$$

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

$$\text{From (5.4b), TBDY: } cu = 0.00548378$$

$$we(5.4c) = 0.00245962$$

$$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00283171$$

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

$$psh_x((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1060.00$$

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

$$A_{sec} \text{ (section area)} = 140000.00$$

$$psh_y((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1060.00$$

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

$$A_{sec} \text{ (section area)} = 140000.00$$

$$s = 210.00$$

$$fy_{we} = 555.55$$

$$f_{ce} = 18.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y1 = 0.00231479$$

```

sh1 = 0.008
ft1 = 666.66
fy1 = 555.55
su1 = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
    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 = 555.55
    with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 1.00
    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 = 555.55
    with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
    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 = 555.55
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.66229413
2 = Asl,com/(b*d)*(fs2/fc) = 0.31447059
v = Asl,mid/(b*d)*(fsv/fc) = 0.58605883
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
    2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
    v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.

```

```

---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
'satisfies Eq. (4.4)
---->
 $v < s, y1$  - LHS eq.(4.7) is not satisfied
---->
 $v < v_c, y1$  - RHS eq.(4.6) is not satisfied
---->
 $c_u$  (4.11) = 0.80684338
 $M_{Rc}$  (4.18) = 2.8814E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core:  $b_o$ ,  $d_o$ ,  $d'_o$ 
-  $N$ ,  $1$ ,  $2$ ,  $v$  normalised to  $b_o * d_o$ , instead of  $b * d$ 
- - parameters of confined concrete,  $f_{cc}$ ,  $c_c$ , used in lieu of  $f_c$ ,  $c_u$ 
---->
Subcase: Rupture of tension steel
---->
 $v^* < v^* s, y2$  - LHS eq.(4.5) is not satisfied
---->
 $v^* < v^* s, c$  - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
 $v^* < v^* c, y2$  - LHS eq.(4.6) is not satisfied
---->
 $v^* < v^* c, y1$  - RHS eq.(4.6) is not satisfied
---->
 $*c_u$  (4.11) = 0.98280667
 $M_{Ro}$  (4.18) = 1.3661E+008
 $M_{Ro} < 0.8 * M_{Rc}$ 
---->
 $u = c_u$  (unconfined full section) = 1.6699237E-005
 $\mu_u = M_{Rc}$ 
-----

Calculation of ratio  $I_b/I_d$ 
-----

Adequate Lap Length:  $I_b/I_d \geq 1$ 
-----

Calculation of  $\mu_{u2}$ -
-----

-----

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:
 $u = 1.0666733E-005$ 
 $\mu_u = 3.9531E+008$ 
-----

with full section properties:
 $b = 450.00$ 
 $d = 407.00$ 
 $d' = 43.00$ 
 $v = 0.42649604$ 
 $N = 1.4060E+006$ 
 $f_c = 18.00$ 
 $c_o$  (5A.5, TBDY) = 0.002
Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.00548378$ 
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY:  $c_u = 0.00548378$ 
 $w_e$  (5.4c) = 0.00245962
 $a_s = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.09380979$ 
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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00283171$

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

-----  
 $p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along Y) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

-----  
 $p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along X) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

-----  
 $s = 210.00$

$f_{ywe} = 555.55$

$f_{ce} = 18.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.002$

$c = \text{confinement factor} = 1.00$

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

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

$l_o/l_{ou,min} = l_b/l_d = 1.00$

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

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

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

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

with  $fs_1 = fs = 555.55$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

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

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$

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

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

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

$y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_2 = fs = 555.55$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$su_v = 0.032$

using (30) in Biskinis/Fardis (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 = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.4973444
MRo (4.18) = 3.9531E+008
---->
u = cu (4.2) = 1.0666733E-005
Mu = MRo
-----

```

Calculation of ratio  $l_b/d$

Adequate Lap Length:  $l_b/d \geq 1$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 229892.529$

Calculation of Shear Strength at edge 1,  $V_{r1} = 229892.529$

$V_{r1} = V_{\text{Col}} \text{ ((10.3), ASCE 41-17)} = k_n l V_{\text{ColO}}$

$V_{\text{ColO}} = 229892.529$

$k_n l = 1$  (zero step-static loading)

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

$= 1$  (normal-weight concrete)

$f'_c = 18.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.2440\text{E}+008$

$\nu_u = 3.7569140\text{E}-005$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.4060\text{E}+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$

where:

$V_{s1} = 0.00$  is calculated for section web, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

$V_{s1}$  is multiplied by  $\text{Col1} = 0.00$

$s/d = 1.3125$

$V_{s2} = 119678.523$  is calculated for section flange, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

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

$s/d = 0.58333333$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 0.00$

From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$

$b_w = 200.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 229892.529$

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

$V_{\text{ColO}} = 229892.529$

$k_n l = 1$  (zero step-static loading)

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

$= 1$  (normal-weight concrete)

$f'_c = 18.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.0841\text{E}+008$

$\nu_u = 3.7569140\text{E}-005$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.4060\text{E}+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$

where:

$V_{s1} = 0.00$  is calculated for section web, with:

$d = 160.00$

Av = 157079.633

fy = 444.44

s = 210.00

Vs1 is multiplied by Col1 = 0.00

s/d = 1.3125

Vs2 = 119678.523 is calculated for section flange, with:

d = 360.00

Av = 157079.633

fy = 444.44

s = 210.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.583333333

Vf ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: Vs + Vf <= 202924.977

bw = 200.00

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1  
At local axis: 2

Integration Section: (a)

Section Type: rdcs

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:

Existing material of Secondary Member: Concrete Strength, fc = fcm = 18.00

Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44

Concrete Elasticity, Ec = 19940.411

Steel Elasticity, Es = 200000.00

Max Height, Hmax = 450.00

Min Height, Hmin = 200.00

Max Width, Wmax = 450.00

Min Width, Wmin = 200.00

Cover Thickness, c = 25.00

Element Length, L = 3000.00

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length (lb/ld >= 1)

No FRP Wrapping

Stepwise Properties

Bending Moment, M = -1.8423E+008

Shear Force, V2 = 87433.392

Shear Force, V3 = -5.71847

Axial Force, F = -1.4055E+006

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: Aslt = 1545.664

-Compression: Aslc = 2576.106

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: Asl,ten = 829.3805

-Compression: Asl,com = 1746.726

-Middle: Asl,mid = 1545.664

Mean Diameter of Tension Reinforcement, DbL = 18.66667

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = \frac{1}{2} u = 0.03467193$   
 $u = y + p = 0.03467193$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.02547133$  ((4.29), Biskinis Phd))  
 $M_y = 3.8889E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 6000.00  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 3.0536E+013$   
factor = 0.70  
 $A_g = 140000.00$   
 $f_c' = 18.00$   
 $N = 1.4055E+006$   
 $E_c * I_g = 4.3623E+013$

Calculation of Yielding Moment  $M_y$

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

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

flange width,  $b = 450.00$   
web width,  $b_w = 200.00$   
flange thickness,  $t = 200.00$

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 9.8163407E-006$   
with  $f_y = 444.44$   
 $d = 407.00$   
 $y = 0.44378959$   
 $A = 0.03977181$   
 $B = 0.02746844$   
with  $p_t = 0.00283171$   
 $p_c = 0.00953713$   
 $p_v = 0.00843933$   
 $N = 1.4055E+006$   
 $b = 450.00$   
 $" = 0.10565111$   
 $y_{comp} = 8.6105988E-006$   
with  $f_c = 18.00$   
 $E_c = 19940.411$   
 $y = 0.46364239$   
 $A = -0.00111008$   
 $B = 0.01020151$   
with  $E_s = 200000.00$   
CONFIRMATION:  $y = 0.46364239 < t/d$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

- Calculation of  $p$  -

From table 10-8:  $p = 0.0092006$

with:

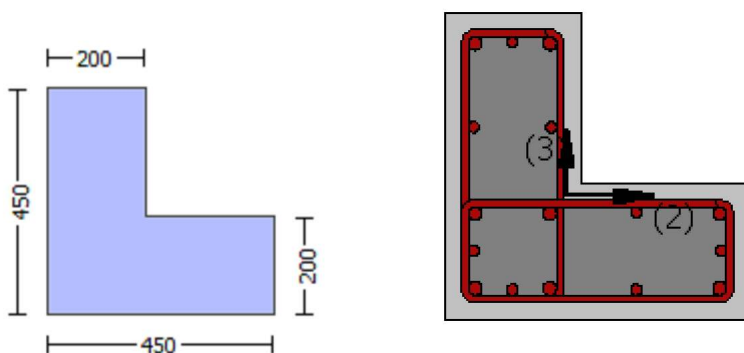
- Columns not controlled by inadequate development or splicing along the clear height because  $I_b/I_d \geq 1$   
shear control ratio  $V_y E / V_{col} O E = 1.14637$   
 $d = 407.00$   
 $s = 150.00$

$t = A_v / (b_w \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = A_v \cdot L_{stir} / (A_g \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00283171$   
 $A_v = 78.53982$ , is the area of every stirrup  
 $L_{stir} = 1060.00$ , is the total Length of all stirrups parallel to loading (shear) direction  
 The term  $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$  is implemented to account for FRP contribution  
 where  $f = 2 \cdot t_f / b_w$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength  
 All these variables have already been given in Shear control ratio calculation.  
 $NUD = 1.4055E+006$   
 $Ag = 140000.00$   
 $f_{cE} = 18.00$   
 $f_{yE} = f_{yIE} = 444.44$   
 $pl = Area\_Tot\_Long\_Rein / (b \cdot d) = 0.02250488$   
 $b = 450.00$   
 $d = 407.00$   
 $f_{cE} = 18.00$

-----  
 End Of Calculation of Chord Rotation Capacity for element: column LC1 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 50 and 51)  
 Analysis: Uniform +X  
 Check: Shear capacity  $VR_d$   
 Edge: Start  
 Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1  
 At local axis: 3  
 Integration Section: (a)  
 Section Type: rdcS  
 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:  
 Existing material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 12.00$   
 Existing material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$   
 Concrete Elasticity,  $E_c = 19940.411$   
 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).  
 Existing material: Concrete Strength,  $f_c = f_{cm} = 18.00$   
 Existing material: Steel Strength,  $f_s = f_{sm} = 444.44$   
 #####  
 Max Height,  $H_{max} = 450.00$   
 Min Height,  $H_{min} = 200.00$   
 Max Width,  $W_{max} = 450.00$   
 Min Width,  $W_{min} = 200.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_o/l_{ou,min} = l_b/l_d \geq 1$ )  
 No FRP Wrapping

#### Stepwise Properties

EDGE -A-  
 Bending Moment,  $M_a = -1.8423E+008$   
 Shear Force,  $V_a = -5.71847$   
 EDGE -B-  
 Bending Moment,  $M_b = 1.1243E+008$   
 Shear Force,  $V_b = 5.71847$   
 BOTH EDGES  
 Axial Force,  $F = -1.4055E+006$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $As_t = 1545.664$   
 -Compression:  $As_c = 2576.106$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{l,ten} = 829.3805$   
 -Compression:  $As_{l,com} = 1746.726$   
 -Middle:  $As_{l,mid} = 1545.664$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = \phi V_n = 206190.061$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n l V_{CoI} = 206190.061$   
 $V_{CoI} = 206190.061$   
 $k_n l = 1.00$   
 $displacement\_ductility\_demand = 0.66893078$

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

$\gamma = 1$  (normal-weight concrete)  
 $f'_c = 12.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $M_u = 1.8423E+008$   
 $V_u = 5.71847$   
 $d = 0.8 \cdot h = 360.00$

$N_u = 1.4055E+006$   
 $A_g = 90000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 107711.748$   
 where:  
 $V_{s1} = 107711.748$  is calculated for section web, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 210.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.58333333$   
 $V_{s2} = 0.00$  is calculated for section flange, with:  
 $d = 160.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 210.00$   
 $V_{s2}$  is multiplied by  $Col2 = 0.00$   
 $s/d = 1.3125$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 165687.55$   
 $b_w = 200.00$

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

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

From analysis, chord rotation  $\theta = 0.01703856$   
 $\phi_y = (M_y * L_s / 3) / E_{eff} = 0.02547133$  ((4.29), Biskinis Phd))  
 $M_y = 3.8889E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) =  $6000.00$   
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 3.0536E+013$   
 $factor = 0.70$   
 $A_g = 140000.00$   
 $f_c' = 18.00$   
 $N = 1.4055E+006$   
 $E_c * I_g = 4.3623E+013$

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,  $b = 450.00$   
 web width,  $b_w = 200.00$   
 flange thickness,  $t = 200.00$

$\phi_y = \text{Min}(\phi_{y\_ten}, \phi_{y\_com})$   
 $\phi_{y\_ten} = 9.8163407E-006$   
 with  $f_y = 444.44$   
 $d = 407.00$   
 $\phi_y = 0.44378959$   
 $A = 0.03977181$   
 $B = 0.02746844$   
 with  $p_t = 0.00452842$   
 $p_c = 0.00953713$   
 $p_v = 0.00843933$   
 $N = 1.4055E+006$   
 $b = 450.00$   
 $\phi_y = 0.10565111$   
 $\phi_{y\_comp} = 8.6105988E-006$   
 with  $f_c = 18.00$   
 $E_c = 19940.411$

$y = 0.46364239$   
 $A = -0.00111008$   
 $B = 0.01020151$   
 with  $E_s = 200000.00$   
 CONFIRMATION:  $y = 0.46364239 < t/d$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

## Calculation No. 12

column C1, Floor 1

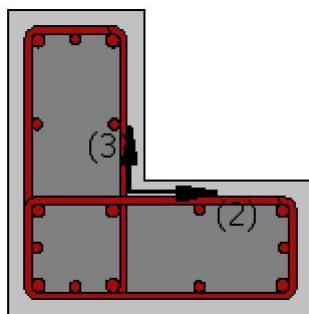
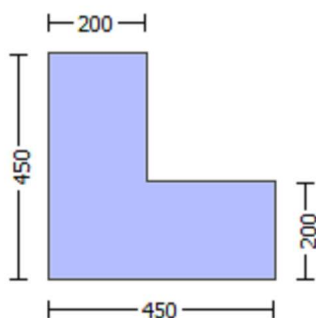
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rdcS

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 18.00$

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

Concrete Elasticity,  $E_c = 19940.411$



```

Steel Elasticity, Es = 200000.00
#####
Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, fs = 1.25*fsm = 555.55
#####
Max Height, Hmax = 450.00
Min Height, Hmin = 200.00
Max Width, Wmax = 450.00
Min Width, Wmin = 200.00
Cover Thickness, c = 25.00
Mean Confinement Factor overall section = 1.00
Element Length, L = 3000.00
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length (lo/lou,min>=1)
No FRP Wrapping
-----

Stepwise Properties
-----
At local axis: 3
EDGE -A-
Shear Force, Va = -8.8389216E-005
EDGE -B-
Shear Force, Vb = 8.8389216E-005
BOTH EDGES
Axial Force, F = -1.4060E+006
Longitudinal Reinforcement Area Distribution (in 2 divisions)
  -Tension: Aslt = 829.3805
  -Compression: Aslc = 3091.327
Longitudinal Reinforcement Area Distribution (in 3 divisions)
  -Tension: Asl,ten = 829.3805
  -Compression: Asl,com = 1746.726
  -Middle: Asl,mid = 1545.664
-----
-----

Calculation of Shear Capacity ratio , Ve/Vr = 1.14637
Member Controlled by Shear (Ve/Vr > 1)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 Ve = (Mpr1 + Mpr2)/ln = 263541.358
with
Mpr1 = Max(Mu1+ , Mu1-) = 3.9531E+008
  Mu1+ = 3.9531E+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- = 2.8814E+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 = Max(Mu2+ , Mu2-) = 3.9531E+008
  Mu2+ = 3.9531E+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- = 2.8814E+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 u according to 4.1, Biskinis/Fardis 2013:
u = 1.0666733E-005
Mu = 3.9531E+008
-----

with full section properties:

```

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.42649604$   
 $N = 1.4060E+006$   
 $f_c = 18.00$   
 $\phi (5A.5, \text{TB DY}) = 0.002$   
 Final value of  $\phi$ :  $\phi^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00548378$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TB DY:  $\phi_u = 0.00548378$   
 $\phi_w (5.4c) = 0.00245962$   
 $\phi_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$   
 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.  
 $A_{conf,max} = 89600.00$  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 perimeter hoops.  
 $A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.  
 $A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i d_i / 6$  as defined at (A.2).  
 $\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00283171$   
 Expression ((5.4d), TB DY) for  $\phi_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

---

$\phi_{sh,x} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$   
 $L_{stir}$  (Length of stirrups along Y) = 1060.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 140000.00

---

$\phi_{sh,y} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$   
 $L_{stir}$  (Length of stirrups along X) = 1060.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 140000.00

---

$s = 210.00$   
 $f_{ywe} = 555.55$   
 $f_{ce} = 18.00$   
 From ((5A.5), TB DY), TB DY:  $\phi_c = 0.002$   
 $\phi_c$  = confinement factor = 1.00  
 $y_1 = 0.00231479$   
 $sh_1 = 0.008$   
 $ft_1 = 666.66$   
 $fy_1 = 555.55$   
 $su_1 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $l_o / l_{ou,min} = l_b / l_d = 1.00$   
 $su_1 = 0.4 * esu_{1,nominal} ((5.5), \text{TB DY}) = 0.032$   
 From table 5A.1, TB DY:  $esu_{1,nominal} = 0.08$ ,  
 For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fs_1 = f_s / 1.2$ , from table 5.1, TB DY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_1 = f_s = 555.55$   
 with  $Es_1 = E_s = 200000.00$   
 $y_2 = 0.00231479$   
 $sh_2 = 0.008$   
 $ft_2 = 666.66$   
 $fy_2 = 555.55$   
 $su_2 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $l_o / l_{ou,min} = l_b / l_{b,min} = 1.00$

```

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 = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
--->
v* < v*sc - LHS eq.(4.5) is not satisfied
--->
Subcase rejected

```

--->  
New Subcase: Failure of compression zone

--->  
 $v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied  
--->  
 $v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied  
--->

\*cu (4.11) = 0.4973444  
MRo (4.18) = 3.9531E+008

--->  
u = cu (4.2) = 1.0666733E-005  
Mu = MRo

-----  
Calculation of ratio lb/ld

-----  
Adequate Lap Length: lb/ld >= 1  
-----  
-----

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

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

u = 1.6699237E-005  
Mu = 2.8814E+008  
-----

with full section properties:

b = 200.00  
d = 407.00  
d' = 43.00  
v = 0.95961609  
N = 1.4060E+006

fc = 18.00  
co (5A.5, TBDY) = 0.002  
Final value of cu:  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00548378$

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

From (5.4b), TBDY:  $cu = 0.00548378$

we (5.4c) = 0.00245962

ase =  $\text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.09380979$

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,max = 89600.00 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 perimeter hoops.

Aconf,min = 21600.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 54733.333 is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min =  $\text{Min}(psh,x, psh,y) = 0.00283171$

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

-----  
 $psh,x \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00283171$

Lstir (Length of stirrups along Y) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00  
-----

$psh,y \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00283171$

Lstir (Length of stirrups along X) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00  
-----

s = 210.00

```

fywe = 555.55
fce = 18.00
From ((5A.5), TBDY), TBDY: cc = 0.002
c = confinement factor = 1.00
y1 = 0.00231479
sh1 = 0.008
ft1 = 666.66
fy1 = 555.55
su1 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.
with fs1 = fs = 555.55
with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.
with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.66229413
2 = Asl,com/(b*d)*(fs2/fc) = 0.31447059
v = Asl,mid/(b*d)*(fsv/fc) = 0.58605883
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfinedsd full section - Steel rupture

```

```

' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.80684338
MRc (4.18) = 2.8814E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N1, N2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, εcc, used in lieu of fc, εcu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.98280667
MRo (4.18) = 1.3661E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 1.6699237E-005
Mu = MRc

```

-----

Calculation of ratio lb/d

-----

Adequate Lap Length: lb/d >= 1

-----

-----

-----

Calculation of Mu2+

-----

-----

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

```

u = 1.0666733E-005
Mu = 3.9531E+008

```

-----

with full section properties:

```

b = 450.00
d = 407.00
d' = 43.00
v = 0.42649604
N = 1.4060E+006
fc = 18.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.00548378

```

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

From (5.4b), TBDY:  $c_u = 0.00548378$

$w_e$  (5.4c) = 0.00245962

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00283171$

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

$p_{sh,x}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along Y) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$p_{sh,y}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along X) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$s = 210.00$

$f_{ywe} = 555.55$

$f_{ce} = 18.00$

From ((5.A5), TBDY), TBDY:  $c_c = 0.002$

$c = \text{confinement factor} = 1.00$

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

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

Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

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

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

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

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

with  $fs_1 = fs = 555.55$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

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

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$

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

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

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

$y_2$ ,  $sh_2$ ,  $ft_2$ ,  $fy_2$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_2 = fs = 555.55$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

```

shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (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 = 1.00
    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 = 555.55
    with Esv = Es = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
    2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
    v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
    2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
    v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
    cu (4.10) = 0.40653976
MRC (4.17) = 4.7962E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
    *cu (4.11) = 0.4973444

```



$$M_{Ro} (4.18) = 3.9531E+008$$

--->

$$u = cu (4.2) = 1.0666733E-005$$

$$Mu = M_{Ro}$$

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of  $Mu_2$ -

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

$$u = 1.6699237E-005$$

$$Mu = 2.8814E+008$$

with full section properties:

$$b = 200.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.95961609$$

$$N = 1.4060E+006$$

$$f_c = 18.00$$

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

$$\text{Final value of } cu: cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00548378$$

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

$$\text{From (5.4b), TBDY: } cu = 0.00548378$$

$$we (5.4c) = 0.00245962$$

$$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00283171$$

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

$$psh_x ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$psh_y ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along X}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 18.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

```

su1 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
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 = 555.55
with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
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 = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.66229413
2 = Asl,com/(b*d)*(fs2/fc) = 0.31447059
v = Asl,mid/(b*d)*(fsv/fc) = 0.58605883
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)

```

```

---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.80684338
MRc (4.18) = 2.8814E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.98280667
MRo (4.18) = 1.3661E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 1.6699237E-005
Mu = MRc

```

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 229892.529$

Calculation of Shear Strength at edge 1,  $V_{r1} = 229892.529$

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

$V_{Co10} = 229892.529$

$knl = 1$  (zero step-static loading)

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

= 1 (normal-weight concrete)

$f'_c = 18.00$ , but  $f_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.2877E+008$

$\nu_u = 8.8389216E-005$

$d = 0.8 * h = 360.00$

$N_u = 1.4060E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$

where:

$V_{s1} = 119678.523$  is calculated for section web, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.58333333$   
 $V_{s2} = 0.00$  is calculated for section flange, with:  
 $d = 160.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 210.00$   
 $V_{s2}$  is multiplied by  $Col2 = 0.00$   
 $s/d = 1.3125$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$   
 $b_w = 200.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 229892.529$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$   
 $V_{Col0} = 229892.529$   
 $knl = 1$  (zero step-static loading)

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

$= 1$  (normal-weight concrete)  
 $f_c' = 18.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 1.1237E+008$   
 $V_u = 8.8389216E-005$   
 $d = 0.8 * h = 360.00$   
 $N_u = 1.4060E+006$   
 $A_g = 90000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$   
 where:  
 $V_{s1} = 119678.523$  is calculated for section web, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 210.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.58333333$   
 $V_{s2} = 0.00$  is calculated for section flange, with:  
 $d = 160.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 210.00$   
 $V_{s2}$  is multiplied by  $Col2 = 0.00$   
 $s/d = 1.3125$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$   
 $b_w = 200.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
 At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
 At Shear local axis: 2  
 (Bending local axis: 3)  
 Section Type: rclcs

Constant Properties

Knowledge Factor,  $= 1.00$   
 Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 18.00$

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

Concrete Elasticity,  $E_c = 19940.411$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height,  $H_{max} = 450.00$

Min Height,  $H_{min} = 200.00$

Max Width,  $W_{max} = 450.00$

Min Width,  $W_{min} = 200.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_o/l_{ou,min} \geq 1$ )

No FRP Wrapping

#### Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = 3.7569140E-005$

EDGE -B-

Shear Force,  $V_b = -3.7569140E-005$

BOTH EDGES

Axial Force,  $F = -1.4060E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 829.3805$

-Compression:  $As_c = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 1746.726$

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

-Middle:  $As_{l,mid} = 1545.664$

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.14637$

Member Controlled by Shear ( $V_e/V_r > 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 263541.358$  with

$M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 3.9531E+008$

$\mu_{u1+} = 2.8814E+008$ , 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

$\mu_{u1-} = 3.9531E+008$ , 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

$M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 3.9531E+008$

$\mu_{u2+} = 2.8814E+008$ , 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

$\mu_{u2-} = 3.9531E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

#### Calculation of $\mu_{u1+}$

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

u = 1.6699237E-005  
Mu = 2.8814E+008

with full section properties:

b = 200.00  
d = 407.00  
d' = 43.00  
v = 0.95961609  
N = 1.4060E+006  
fc = 18.00  
co (5A.5, TBDY) = 0.002  
Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.00548378  
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY: cu = 0.00548378  
we (5.4c) = 0.00245962  
ase = Max(((Aconf,max-AnoConf)/Aconf,max)\*(Aconf,min/Aconf,max),0) = 0.09380979  
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,max = 89600.00 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 perimeter hoops.  
Aconf,min = 21600.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.  
AnoConf = 54733.333 is the unconfined core area which is equal to bi2/6 as defined at (A.2).  
psh,min = Min(psh,x , psh,y) = 0.00283171  
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00283171  
Lstir (Length of stirrups along Y) = 1060.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 140000.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00283171  
Lstir (Length of stirrups along X) = 1060.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 140000.00

s = 210.00  
fywe = 555.55  
fce = 18.00  
From ((5.A5), TBDY), TBDY: cc = 0.002  
c = confinement factor = 1.00  
y1 = 0.00231479  
sh1 = 0.008  
ft1 = 666.66  
fy1 = 555.55  
su1 = 0.032  
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00  
su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032  
From table 5A.1, TBDY: esu1\_nominal = 0.08,  
For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.  
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.  
with fs1 = fs = 555.55  
with Es1 = Es = 200000.00  
y2 = 0.00231479  
sh2 = 0.008  
ft2 = 666.66  
fy2 = 555.55  
su2 = 0.032

```

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
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 = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.66229413
2 = Asl,com/(b*d)*(fs2/fc) = 0.31447059
v = Asl,mid/(b*d)*(fsv/fc) = 0.58605883
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < s,y1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is not satisfied
--->
cu (4.11) = 0.80684338
MRc (4.18) = 2.8814E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied

```

```

---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.98280667
MRo (4.18) = 1.3661E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 1.6699237E-005
Mu = MRc
-----

Calculation of ratio lb/ld
-----
Adequate Lap Length: lb/ld >= 1
-----
-----
Calculation of Mu1-
-----
-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.0666733E-005
Mu = 3.9531E+008
-----

with full section properties:
b = 450.00
d = 407.00
d' = 43.00
v = 0.42649604
N = 1.4060E+006
fc = 18.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.00548378
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.00548378
we (5.4c) = 0.00245962
ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.09380979
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,max = 89600.00 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 perimeter hoops.
Aconf,min = 21600.00 is the confined core area at midway between the levels of hoops and
is calculated by reducing all the dimensions of the area Aconf,max by a length
equal to half the clear spacing between hoops.
AnoConf = 54733.333 is the unconfined core area which is equal to bi2/6 as defined at (A.2).
psh,min = Min(psh,x , psh,y) = 0.00283171
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without
earthquake detailing (90° closed stirrups)
-----
psh,x ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00283171
Lstir (Length of stirrups along Y) = 1060.00
Astir (stirrups area) = 78.53982
Asec (section area) = 140000.00
-----
psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00283171

```



Lstir (Length of stirrups along X) = 1060.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 140000.00

s = 210.00

fywe = 555.55

fce = 18.00

From ((5A.5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

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

lo/lou,min = lb/lb = 1.00

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 = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

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

lo/lou,min = lb/lb,min = 1.00

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 = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

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

lo/lou,min = lb/lb = 1.00

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 = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.13976471

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.29435295

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.26047059

and confined core properties:

b = 390.00

d = 377.00

d' = 13.00

fcc (5A.2, TBDY) = 18.00

cc (5A.5, TBDY) = 0.002

```

c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
--->
v* < v*sc - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
--->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
--->
*cu (4.11) = 0.4973444
MRo (4.18) = 3.9531E+008
--->
u = cu (4.2) = 1.0666733E-005
Mu = MRo
-----

Calculation of ratio lb/d
-----
Adequate Lap Length: lb/d >= 1
-----
-----

Calculation of Mu2+
-----
-----

-----
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.6699237E-005
Mu = 2.8814E+008
-----

with full section properties:
b = 200.00
d = 407.00
d' = 43.00
v = 0.95961609

```

$N = 1.4060E+006$   
 $f_c = 18.00$   
 $\alpha (5A.5, TBDY) = 0.002$   
 Final value of  $\alpha$ :  $\alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.00548378$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\alpha = 0.00548378$   
 $\alpha_e (5.4c) = 0.00245962$   
 $\alpha_{se} = \text{Max}(((\alpha_{conf,max} - \alpha_{noConf}) / \alpha_{conf,max}) * (\alpha_{conf,min} / \alpha_{conf,max}), 0) = 0.09380979$   
 The definitions of  $\alpha_{noConf}$ ,  $\alpha_{conf,min}$  and  $\alpha_{conf,max}$  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.  
 $\alpha_{conf,max} = 89600.00$  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 perimeter hoops.  
 $\alpha_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $\alpha_{conf,max}$  by a length equal to half the clear spacing between hoops.  
 $\alpha_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $\alpha_{sh,min} = \text{Min}(\alpha_{sh,x}, \alpha_{sh,y}) = 0.00283171$   
 Expression ((5.4d), TBDY) for  $\alpha_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

---

$\alpha_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$   
 $L_{stir}$  (Length of stirrups along Y) = 1060.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 140000.00

---

$\alpha_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$   
 $L_{stir}$  (Length of stirrups along X) = 1060.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 140000.00

---

$s = 210.00$   
 $f_{ywe} = 555.55$   
 $f_{ce} = 18.00$   
 From ((5.A5), TBDY), TBDY:  $\alpha_c = 0.002$   
 $\alpha_c$  = confinement factor = 1.00  
 $y_1 = 0.00231479$   
 $sh_1 = 0.008$   
 $ft_1 = 666.66$   
 $fy_1 = 555.55$   
 $su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 1.00$   
 $su_1 = 0.4 * \alpha_{su1\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $\alpha_{su1\_nominal} = 0.08$ ,  
 For calculation of  $\alpha_{su1\_nominal}$  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  $fs_1 = fs = 555.55$   
 with  $E_{s1} = E_s = 200000.00$

$y_2 = 0.00231479$   
 $sh_2 = 0.008$   
 $ft_2 = 666.66$   
 $fy_2 = 555.55$   
 $su_2 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$   
 $su_2 = 0.4 * \alpha_{su2\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $\alpha_{su2\_nominal} = 0.08$ ,  
 For calculation of  $\alpha_{su2\_nominal}$  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.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs2 = fs = 555.55$   
 with  $Es2 = Es = 200000.00$   
 $yv = 0.00231479$   
 $shv = 0.008$   
 $ftv = 666.66$   
 $fyv = 555.55$   
 $suv = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou, min = lb/ld = 1.00$   
 $suv = 0.4 \cdot esuv\_nominal \cdot ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = fs = 555.55$   
 with  $Es = Es = 200000.00$   
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.66229413$   
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.31447059$   
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.58605883$

and confined core properties:

$b = 140.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc \text{ (5A.2, TBDY)} = 18.00$   
 $cc \text{ (5A.5, TBDY)} = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 1.02142$   
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.48499254$   
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.90384974$

Case/Assumption: Unconfined full section - Steel rupture  
 ' does not satisfy Eq. (4.3)

--->  
 $v < v_{s,c}$  - RHS eq.(4.5) is not satisfied

--->  
 Case/Assumption Rejected.

--->  
 New Case/Assumption: Unconfined full section - Spalling of concrete cover  
 ' satisfies Eq. (4.4)

--->  
 $v < s_{y1}$  - LHS eq.(4.7) is not satisfied

--->  
 $v < v_{c,y1}$  - RHS eq.(4.6) is not satisfied

--->  
 $cu \text{ (4.11)} = 0.80684338$   
 $MRC \text{ (4.18)} = 2.8814E+008$

--->  
 New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover  
 In expressions below, the following modifications have been made  
 -  $b, d, d'$  replaced by geometric parameters of the core:  $bo, do, d'o$   
 -  $N, 1, 2, v$  normalised to  $bo \cdot do$ , instead of  $b \cdot d$   
 - parameters of confined concrete,  $fcc, cc$ , used in lieu of  $fc, ecu$

--->  
 Subcase: Rupture of tension steel

--->  
 $v^* < v^* s_{y2}$  - LHS eq.(4.5) is not satisfied

--->  
 $v^* < v^* s_{c,c}$  - LHS eq.(4.5) is not satisfied

--->  
 Subcase rejected

--->  
 New Subcase: Failure of compression zone

--->  
 $v^* < v^* c_{y2}$  - LHS eq.(4.6) is not satisfied

--->  
 $v^* < v^*c, y1$  - RHS eq.(4.6) is not satisfied

--->  
 $*cu(4.11) = 0.98280667$   
 $M_{Ro}(4.18) = 1.3661E+008$   
 $M_{Ro} < 0.8*M_{Rc}$

--->  
 $u = cu(\text{unconfined full section}) = 1.6699237E-005$   
 $\mu = M_{Rc}$

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of  $\mu_2$ -

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

$u = 1.0666733E-005$   
 $\mu = 3.9531E+008$

with full section properties:

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.42649604$   
 $N = 1.4060E+006$

$f_c = 18.00$   
 $\alpha(5A.5, \text{TBDY}) = 0.002$   
Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00548378$

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

From (5.4b), TBDY:  $cu = 0.00548378$

we (5.4c)  $= 0.00245962$

$ase = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.09380979$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00283171$

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

$p_{sh,x}((5.4d), \text{TBDY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along Y) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$p_{sh,y}((5.4d), \text{TBDY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along X) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$s = 210.00$

$f_{ywe} = 555.55$

$f_{ce} = 18.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.002$

```

c = confinement factor = 1.00
y1 = 0.00231479
sh1 = 0.008
ft1 = 666.66
fy1 = 555.55
su1 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
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 = 555.55
with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
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 = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied

```

```

---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
'satisfies Eq. (4.4)
---->
 $v < s_y1$  - LHS eq.(4.7) is not satisfied
---->
 $v < v_{c,y1}$  - RHS eq.(4.6) is satisfied
---->
 $c_u$  (4.10) = 0.40653976
 $M_{Rc}$  (4.17) = 4.7962E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core:  $b_o$ ,  $d_o$ ,  $d'_o$ 
-  $N_1$ ,  $N_2$ ,  $v$  normalised to  $b_o*d_o$ , instead of  $b*d$ 
- - parameters of confined concrete,  $f_{cc}$ ,  $\epsilon_{cc}$ , used in lieu of  $f_c$ ,  $\epsilon_{cu}$ 
---->
Subcase: Rupture of tension steel
---->
 $v^* < v^*s_y2$  - LHS eq.(4.5) is not satisfied
---->
 $v^* < v^*s_{c,c}$  - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
 $v^* < v^*c_y2$  - LHS eq.(4.6) is not satisfied
---->
 $v^* < v^*c_y1$  - RHS eq.(4.6) is not satisfied
---->
 $*c_u$  (4.11) = 0.4973444
 $M_{Ro}$  (4.18) = 3.9531E+008
---->
 $u = c_u$  (4.2) = 1.0666733E-005
 $\mu = M_{Ro}$ 

```

-----

Calculation of ratio  $l_b/l_d$

-----

Adequate Lap Length:  $l_b/l_d \geq 1$

-----

-----

-----

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 229892.529$

-----

Calculation of Shear Strength at edge 1,  $V_{r1} = 229892.529$

$V_{r1} = V_{Co1}$  ((10.3), ASCE 41-17) =  $k_n l^* V_{Co10}$

$V_{Co10} = 229892.529$

$k_n l = 1$  (zero step-static loading)

-----

NOTE: In expression (10-3) ' $V_s$ ' is replaced by ' $V_{s+} + f^* V_f$ '  
where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

-----

$= 1$  (normal-weight concrete)

$f'_c = 18.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.2440E+008$

$V_u = 3.7569140E-005$

$d = 0.8*h = 360.00$

$N_u = 1.4060E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$

where:

Vs1 = 0.00 is calculated for section web, with:

$$d = 160.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 210.00$$

Vs1 is multiplied by Col1 = 0.00

$$s/d = 1.3125$$

Vs2 = 119678.523 is calculated for section flange, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 210.00$$

Vs2 is multiplied by Col2 = 1.00

$$s/d = 0.58333333$$

Vf ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: Vs + Vf <= 202924.977

$$bw = 200.00$$

Calculation of Shear Strength at edge 2, Vr2 = 229892.529

Vr2 = VCol ((10.3), ASCE 41-17) = knl\*VCol0

$$VCol0 = 229892.529$$

knl = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)

fc' = 18.00, but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$\mu_u = 1.0841E+008$$

$$\nu_u = 3.7569140E-005$$

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

$$N_u = 1.4060E+006$$

$$A_g = 90000.00$$

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 119678.523

where:

Vs1 = 0.00 is calculated for section web, with:

$$d = 160.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 210.00$$

Vs1 is multiplied by Col1 = 0.00

$$s/d = 1.3125$$

Vs2 = 119678.523 is calculated for section flange, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 210.00$$

Vs2 is multiplied by Col2 = 1.00

$$s/d = 0.58333333$$

Vf ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: Vs + Vf <= 202924.977

$$bw = 200.00$$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rdc



## 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:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 18.00$

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

Concrete Elasticity,  $E_c = 19940.411$

Steel Elasticity,  $E_s = 200000.00$

Max Height,  $H_{max} = 450.00$

Min Height,  $H_{min} = 200.00$

Max Width,  $W_{max} = 450.00$

Min Width,  $W_{min} = 200.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_b/d \geq 1$ )

No FRP Wrapping

## Stepwise Properties

Bending Moment,  $M = -1.2613E+008$

Shear Force,  $V_2 = 87433.392$

Shear Force,  $V_3 = -5.71847$

Axial Force,  $F = -1.4055E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{slt} = 1545.664$

-Compression:  $A_{slc} = 2576.106$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten} = 1746.726$

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

-Middle:  $A_{sl,mid} = 1545.664$

Mean Diameter of Tension Reinforcement,  $DbL = 17.71429$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = \phi \cdot u = 0.01237958$

$u = y + p = 0.01237958$

- Calculation of  $y$  -

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00317898$  ((4.29), Biskinis Phd))

$M_y = 2.0187E+008$

$L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 1442.605

From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 3.0536E+013$

factor = 0.70

$A_g = 140000.00$

$f_c' = 18.00$

$N = 1.4055E+006$

$E_c \cdot I_g = 4.3623E+013$

Calculation of Yielding Moment  $M_y$

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

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

$y_{ten} = 1.3705984E-005$

with  $f_y = 444.44$   
 $d = 407.00$   
 $y = 0.60163744$   
 $A = 0.08948658$   
 $B = 0.07188293$   
 with  $p_t = 0.00283171$   
 $p_c = 0.01018895$   
 $p_v = 0.0189885$   
 $N = 1.4055E+006$   
 $b = 200.00$   
 $" = 0.10565111$   
 $y_{comp} = 4.7557658E-006$   
 with  $f_c = 18.00$   
 $E_c = 19940.411$   
 $y = 0.83945231$   
 $A = -0.00249769$   
 $B = 0.03303234$   
 with  $E_s = 200000.00$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

- Calculation of  $p$  -

From table 10-8:  $p = 0.0092006$

with:

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

shear control ratio  $V_y E/V_{col} E = 1.14637$

$d = 407.00$

$s = 150.00$

$t = A_v/(b w s) + 2 t_f/b w (f_{fe}/f_s) = A_v L_{stir}/(A_g s) + 2 t_f/b w (f_{fe}/f_s) = 0.00283171$

$A_v = 78.53982$ , is the area of every stirrup

$L_{stir} = 1060.00$ , is the total Length of all stirrups parallel to loading (shear) direction

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

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

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

$N_{UD} = 1.4055E+006$

$A_g = 140000.00$

$f_{cE} = 18.00$

$f_{yE} = f_{yI} = 444.44$

$p_l = \text{Area\_Tot\_Long\_Rein}/(b d) = 0.05063599$

$b = 200.00$

$d = 407.00$

$f_{cE} = 18.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

**Calculation No. 13**

column C1, Floor 1

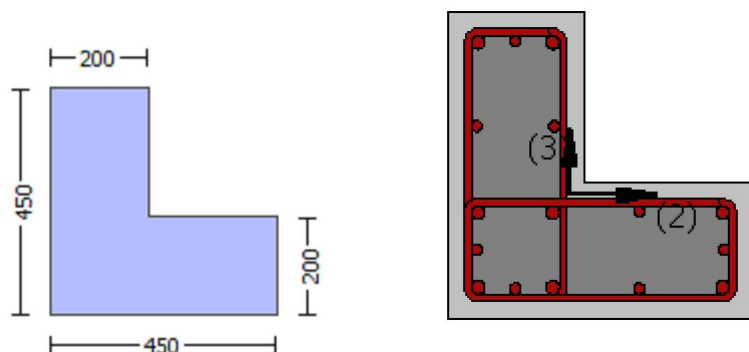
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rclcs

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:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 12.00$

Existing material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$

Concrete Elasticity,  $E_c = 19940.411$

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).

Existing material: Concrete Strength,  $f_c = f_{cm} = 18.00$

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

#####

Max Height,  $H_{max} = 450.00$

Min Height,  $H_{min} = 200.00$

Max Width,  $W_{max} = 450.00$

Min Width,  $W_{min} = 200.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_o/l_{ou,min} = l_b/l_d \geq 1$ )

No FRP Wrapping

Stepwise Properties

EDGE -A-  
 Bending Moment,  $M_a = -1.2613E+008$   
 Shear Force,  $V_a = 87433.392$   
 EDGE -B-  
 Bending Moment,  $M_b = 1.2593E+008$   
 Shear Force,  $V_b = -87433.392$   
 BOTH EDGES  
 Axial Force,  $F = -1.4055E+006$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{sl,t} = 829.3805$   
   -Compression:  $A_{sl,c} = 3292.389$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{sl,ten} = 1746.726$   
   -Compression:  $A_{sl,com} = 829.3805$   
   -Middle:  $A_{sl,mid} = 1545.664$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = V_n = 206190.061$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{CoI} = 206190.061$   
 $V_{CoI} = 206190.061$   
 $k_n = 1.00$   
 $displacement\_ductility\_demand = 1.24072$

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

$\phi = 1$  (normal-weight concrete)  
 $f'_c = 12.00$ , but  $f_c^{0.5} \leq 8.3$  MPa ((22.5.3.1, ACI 318-14))  
 $M/Vd = 4.00$   
 $M_u = 1.2593E+008$   
 $V_u = 87433.392$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 1.4055E+006$   
 $A_g = 90000.00$   
 From ((11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 107711.748$   
 where:  
 $V_{s1} = 0.00$  is calculated for section web, with:  
 $d = 160.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 210.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.00$   
 $s/d = 1.3125$   
 $V_{s2} = 107711.748$  is calculated for section flange, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 210.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.58333333$   
 $V_f$  ((11-3)-(11.4), ACI 440) =  $0.00$   
 From ((11-11), ACI 440:  $V_s + V_f \leq 165687.55$   
 $bw = 200.00$

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

- Calculation of  $\phi / y$  for END B -  
 for rotation axis 3 and integ. section (b)

From analysis, chord rotation  $\theta = 0.00393801$   
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00317398$  ((4.29), Biskinis Phd))  
 $M_y = 2.0187E+008$

$L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 1440.333  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 3.0536E+013$   
factor = 0.70  
Ag = 140000.00  
fc' = 18.00  
N = 1.4055E+006  
 $E_c \cdot I_g = 4.3623E+013$

Calculation of Yielding Moment  $M_y$

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

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 1.3705984E-005$   
with  $f_y = 444.44$   
d = 407.00  
 $y = 0.60163744$   
A = 0.08948658  
B = 0.07188293  
with  $p_t = 0.02145854$   
pc = 0.01018895  
pv = 0.0189885  
N = 1.4055E+006  
b = 200.00  
" = 0.10565111  
 $y_{comp} = 4.7557658E-006$   
with  $f_c = 18.00$   
 $E_c = 19940.411$   
 $y = 0.83945231$   
A = -0.00249769  
B = 0.03303234  
with  $E_s = 200000.00$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 14

column C1, Floor 1

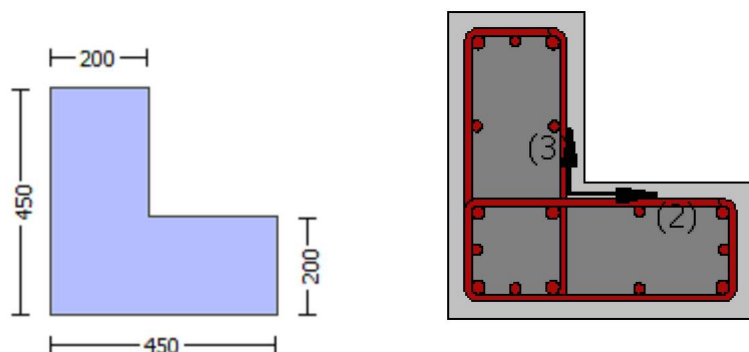
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rclcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 18.00$

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

Concrete Elasticity,  $E_c = 19940.411$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height,  $H_{max} = 450.00$

Min Height,  $H_{min} = 200.00$

Max Width,  $W_{max} = 450.00$

Min Width,  $W_{min} = 200.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_o/l_{ou,min} \geq 1$ )

No FRP Wrapping

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = -8.8389216E-005$

EDGE -B-

Shear Force,  $V_b = 8.8389216E-005$

BOTH EDGES

Axial Force,  $F = -1.4060E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 829.3805$

-Compression:  $As_c = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

-Compression:  $As_{c,com} = 1746.726$

-Middle:  $As_{c,mid} = 1545.664$

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.14637$

Member Controlled by Shear ( $V_e/V_r > 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 263541.358$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 3.9531E+008$

$Mu_{1+} = 3.9531E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.8814E+008$ , 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 3.9531E+008$

$Mu_{2+} = 3.9531E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.8814E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $Mu_{1+}$

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

$\phi_u = 1.0666733E-005$

$M_u = 3.9531E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.42649604$

$N = 1.4060E+006$

$f_c = 18.00$

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

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00548378$

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

From (5.4b), TBDY:  $\phi_u = 0.00548378$

$\phi_{ue} (5.4c) = 0.00245962$

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.09380979$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00283171$

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

$$psh,x ((5.4d), TBDY) = Lstir \cdot Astir / (Asec \cdot s) = 0.00283171$$

$$Lstir \text{ (Length of stirrups along Y)} = 1060.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 140000.00$$

$$psh,y ((5.4d), TBDY) = Lstir \cdot Astir / (Asec \cdot s) = 0.00283171$$

$$Lstir \text{ (Length of stirrups along X)} = 1060.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 140000.00$$

$$s = 210.00$$

$$fywe = 555.55$$

$$fce = 18.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

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

$$lo/lou,min = lb/ld = 1.00$$

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

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

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

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

$$\text{with } fs1 = fs = 555.55$$

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

$$y2 = 0.00231479$$

$$sh2 = 0.008$$

$$ft2 = 666.66$$

$$fy2 = 555.55$$

$$su2 = 0.032$$

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

$$lo/lou,min = lb/lb,min = 1.00$$

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

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

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

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

$$\text{with } fs2 = fs = 555.55$$

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

$$yv = 0.00231479$$

$$shv = 0.008$$

$$ftv = 666.66$$

$$fyv = 555.55$$

$$suv = 0.032$$

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

$$lo/lou,min = lb/ld = 1.00$$

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

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

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

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

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

$$\text{with } fsv = fs = 555.55$$

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

$$1 = Asl,ten/(b \cdot d) \cdot (fs1/fc) = 0.13976471$$

$$2 = Asl,com/(b \cdot d) \cdot (fs2/fc) = 0.29435295$$



```

v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < s,y1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
--->
v* < v*s,c - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
--->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
--->
*cu (4.11) = 0.4973444
MRo (4.18) = 3.9531E+008
--->
u = cu (4.2) = 1.0666733E-005
Mu = MRo

```

-----

Calculation of ratio lb/d

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Adequate Lap Length: lb/d >= 1

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Calculation of Mu1-

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-----

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

u = 1.6699237E-005

$$\mu = 2.8814E+008$$

with full section properties:

$$b = 200.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.95961609$$

$$N = 1.4060E+006$$

$$f_c = 18.00$$

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

$$\text{Final value of } \phi: \phi^* = \text{shear\_factor} * \text{Max}(\phi_c, \phi_s) = 0.00548378$$

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

$$\text{From (5.4b), TB DY: } \phi_c = 0.00548378$$

$$\phi_s (5.4c) = 0.00245962$$

$$\phi_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b^2/6$  as defined at (A.2).

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00283171$$

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

$$\phi_{sh,x} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$\phi_{sh,y} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along X}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 18.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \phi_c = 0.002$$

$$\phi_c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

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

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

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, TB DY.

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

$$\text{with } fs_1 = fs = 555.55$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

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

and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_{b,min} = 1.00$   
 $\phi_{su2} = 0.4 \cdot \phi_{su2,nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $\phi_{su2,nominal} = 0.08$ ,  
For calculation of  $\phi_{su2,nominal}$  and  $\phi_{y2}, \phi_{sh2}, \phi_{ft2}, \phi_{fy2}$ , it is considered  
characteristic value  $\phi_{sy2} = \phi_{s2}/1.2$ , from table 5.1, TBDY.  
 $\phi_{y1}, \phi_{sh1}, \phi_{ft1}, \phi_{fy1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $\phi_{s2} = \phi_s = 555.55$   
with  $E_{s2} = E_s = 200000.00$   
 $\phi_{yv} = 0.00231479$   
 $\phi_{shv} = 0.008$   
 $\phi_{ftv} = 666.66$   
 $\phi_{fyv} = 555.55$   
 $\phi_{suv} = 0.032$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 1.00$   
 $\phi_{suv} = 0.4 \cdot \phi_{suv,nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $\phi_{suv,nominal} = 0.08$ ,  
considering characteristic value  $\phi_{fsv} = \phi_{sv}/1.2$ , from table 5.1, TBDY  
For calculation of  $\phi_{suv,nominal}$  and  $\phi_{yv}, \phi_{shv}, \phi_{ftv}, \phi_{fyv}$ , it is considered  
characteristic value  $\phi_{fsv} = \phi_{sv}/1.2$ , from table 5.1, TBDY.  
 $\phi_{y1}, \phi_{sh1}, \phi_{ft1}, \phi_{fy1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $\phi_{sv} = \phi_s = 555.55$   
with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (\phi_{s1}/\phi_c) = 0.66229413$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (\phi_{s2}/\phi_c) = 0.31447059$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (\phi_{sv}/\phi_c) = 0.58605883$   
and confined core properties:  
 $b = 140.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $\phi_{cc} (5A.2, TBDY) = 18.00$   
 $\phi_{cc} (5A.5, TBDY) = 0.002$   
 $\phi_c = \text{confinement factor} = 1.00$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (\phi_{s1}/\phi_c) = 1.02142$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (\phi_{s2}/\phi_c) = 0.48499254$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (\phi_{sv}/\phi_c) = 0.90384974$   
Case/Assumption: Unconfined full section - Steel rupture  
' does not satisfy Eq. (4.3)  
--->  
 $v < v_{s,c}$  - RHS eq.(4.5) is not satisfied  
--->  
Case/Assumption Rejected.  
--->  
New Case/Assumption: Unconfined full section - Spalling of concrete cover  
' satisfies Eq. (4.4)  
--->  
 $v < s_{y1}$  - LHS eq.(4.7) is not satisfied  
--->  
 $v < v_{c,y1}$  - RHS eq.(4.6) is not satisfied  
--->  
 $\phi_{cu} (4.11) = 0.80684338$   
 $M_{Rc} (4.18) = 2.8814E+008$   
--->  
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover  
In expressions below, the following modifications have been made  
-  $b, d, d'$  replaced by geometric parameters of the core:  $b_o, d_o, d'_o$   
-  $N, 1, 2, v$  normalised to  $b_o \cdot d_o$ , instead of  $b \cdot d$   
-  $\phi_{cc}$  parameters of confined concrete,  $\phi_{cc}$ , used in lieu of  $\phi_c, \phi_{cu}$   
--->  
Subcase: Rupture of tension steel  
--->  
 $v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied  
--->

$v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

$v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied

--->

$v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied

--->

$*c_u$  (4.11) = 0.98280667

$M_{Ro}$  (4.18) = 1.3661E+008

$M_{Ro} < 0.8 * M_{Rc}$

--->

$u = c_u$  (unconfined full section) = 1.6699237E-005

$\mu = M_{Rc}$

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of  $\mu_{2+}$

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

$u = 1.0666733E-005$

$\mu = 3.9531E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.42649604$

$N = 1.4060E+006$

$f_c = 18.00$

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

Final value of  $c_u$ :  $c_u = \text{shear\_factor} * \text{Max}(c_u, \alpha) = 0.00548378$

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

From (5.4b), TBDY:  $c_u = 0.00548378$

$w_e$  (5.4c) = 0.00245962

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00283171$

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

$p_{sh,x}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along Y) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$p_{sh,y}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along X) = 1060.00

Astir (stirrups area) = 78.53982  
Asec (section area) = 140000.00

s = 210.00

fywe = 555.55

fce = 18.00

From ((5.A.5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

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

lo/lou,min = lb/lb = 1.00

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 = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

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

lo/lou,min = lb/lb,min = 1.00

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 = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

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

lo/lou,min = lb/lb = 1.00

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 = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.13976471

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.29435295

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.26047059

and confined core properties:

b = 390.00

d = 377.00

d' = 13.00

fcc (5A.2, TBDY) = 18.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

```

1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.4973444
MRo (4.18) = 3.9531E+008
---->
u = cu (4.2) = 1.0666733E-005
Mu = MRo
-----

Calculation of ratio lb/ld
-----
Adequate Lap Length: lb/ld >= 1
-----

Calculation of Mu2-
-----

-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.6699237E-005
Mu = 2.8814E+008
-----

with full section properties:
b = 200.00
d = 407.00
d' = 43.00
v = 0.95961609
N = 1.4060E+006

```

$f_c = 18.00$   
 $\alpha (5A.5, TBDY) = 0.002$   
 Final value of  $\alpha$ :  $\alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.00548378$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\alpha = 0.00548378$   
 $\alpha_e (5.4c) = 0.00245962$   
 $\alpha_{se} = \text{Max}(((\alpha_{conf,max} - \alpha_{noConf}) / \alpha_{conf,max}) * (\alpha_{conf,min} / \alpha_{conf,max}), 0) = 0.09380979$   
 The definitions of  $\alpha_{noConf}$ ,  $\alpha_{conf,min}$  and  $\alpha_{conf,max}$  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.  
 $\alpha_{conf,max} = 89600.00$  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 perimeter hoops.  
 $\alpha_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $\alpha_{conf,max}$  by a length equal to half the clear spacing between hoops.  
 $\alpha_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $\alpha_{sh,min} = \text{Min}(\alpha_{sh,x}, \alpha_{sh,y}) = 0.00283171$   
 Expression ((5.4d), TBDY) for  $\alpha_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\alpha_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$   
 $L_{stir}$  (Length of stirrups along Y) = 1060.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 140000.00

$\alpha_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$   
 $L_{stir}$  (Length of stirrups along X) = 1060.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 140000.00

$s = 210.00$   
 $f_{ywe} = 555.55$   
 $f_{ce} = 18.00$

From ((5A5), TBDY), TBDY:  $\alpha_c = 0.002$   
 $\alpha_c$  = confinement factor = 1.00

$y_1 = 0.00231479$   
 $sh_1 = 0.008$   
 $ft_1 = 666.66$   
 $fy_1 = 555.55$   
 $su_1 = 0.032$

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

$su_1 = 0.4 * \alpha_{su1\_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $\alpha_{su1\_nominal} = 0.08$ ,

For calculation of  $\alpha_{su1\_nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = f_s/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_1 = f_s = 555.55$   
 with  $E_{s1} = E_s = 200000.00$

$y_2 = 0.00231479$   
 $sh_2 = 0.008$   
 $ft_2 = 666.66$   
 $fy_2 = 555.55$   
 $su_2 = 0.032$

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

$su_2 = 0.4 * \alpha_{su2\_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $\alpha_{su2\_nominal} = 0.08$ ,

For calculation of  $\alpha_{su2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $fsy_2 = f_s/1.2$ , from table 5.1, TBDY.

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

```

with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.66229413
2 = Asl,com/(b*d)*(fs2/fc) = 0.31447059
v = Asl,mid/(b*d)*(fsv/fc) = 0.58605883
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < s,y1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is not satisfied
--->
cu (4.11) = 0.80684338
MRc (4.18) = 2.8814E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
--->
v* < v*s,c - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
--->

```



$v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied

--->

$$*cu(4.11) = 0.98280667$$

$$MRo(4.18) = 1.3661E+008$$

$$MRo < 0.8*MRc$$

--->

$$u = cu(\text{unconfined full section}) = 1.6699237E-005$$

$$Mu = MRc$$

Calculation of ratio  $lb/d$

Adequate Lap Length:  $lb/d \geq 1$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 229892.529$

Calculation of Shear Strength at edge 1,  $V_{r1} = 229892.529$

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

$$V_{Col0} = 229892.529$$

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

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

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

$$f'_c = 18.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$Mu = 1.2877E+008$$

$$Vu = 8.8389216E-005$$

$$d = 0.8*h = 360.00$$

$$Nu = 1.4060E+006$$

$$Ag = 90000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 119678.523$$

where:

$V_{s1} = 119678.523$  is calculated for section web, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 210.00$$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$$s/d = 0.58333333$$

$V_{s2} = 0.00$  is calculated for section flange, with:

$$d = 160.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 210.00$$

$V_{s2}$  is multiplied by  $Col2 = 0.00$

$$s/d = 1.3125$$

$$V_f((11-3)-(11.4), \text{ACI 440}) = 0.00$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 202924.977$$

$$bw = 200.00$$

Calculation of Shear Strength at edge 2,  $V_{r2} = 229892.529$

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

$$V_{Col0} = 229892.529$$

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

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

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

$$f'_c = 18.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$\mu_u = 1.1237E+008$   
 $V_u = 8.8389216E-005$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 1.4060E+006$   
 $A_g = 90000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$   
 where:  
 $V_{s1} = 119678.523$  is calculated for section web, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 210.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.58333333$   
 $V_{s2} = 0.00$  is calculated for section flange, with:  
 $d = 160.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 210.00$   
 $V_{s2}$  is multiplied by  $Col2 = 0.00$   
 $s/d = 1.3125$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$   
 $b_w = 200.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
 At local axis: 3  
 -----

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
 At Shear local axis: 2  
 (Bending local axis: 3)  
 Section Type: rdlcs

#### Constant Properties

-----  
 Knowledge Factor,  $\phi = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 18.00$   
 Existing material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
 Concrete Elasticity,  $E_c = 19940.411$   
 Steel Elasticity,  $E_s = 200000.00$   
 #####  
 Note: Especially for the calculation of moment strengths,  
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$   
 #####  
 Max Height,  $H_{max} = 450.00$   
 Min Height,  $H_{min} = 200.00$   
 Max Width,  $W_{max} = 450.00$   
 Min Width,  $W_{min} = 200.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.00  
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_o/l_{ou,min} \geq 1$ )  
 No FRP Wrapping  
 -----

## Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = 3.7569140E-005$

EDGE -B-

Shear Force,  $V_b = -3.7569140E-005$

BOTH EDGES

Axial Force,  $F = -1.4060E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 829.3805$

-Compression:  $As_c = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 1746.726$

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

-Middle:  $As_{l,mid} = 1545.664$

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.14637$

Member Controlled by Shear ( $V_e/V_r > 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 263541.358$   
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 3.9531E+008$

$\mu_{1+} = 2.8814E+008$ , 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

$\mu_{1-} = 3.9531E+008$ , 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 3.9531E+008$

$\mu_{2+} = 2.8814E+008$ , 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

$\mu_{2-} = 3.9531E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $\mu_{1+}$

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

$\phi_u = 1.6699237E-005$

$\mu_u = 2.8814E+008$

with full section properties:

$b = 200.00$

$d = 407.00$

$d' = 43.00$

$\nu = 0.95961609$

$N = 1.4060E+006$

$f_c = 18.00$

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

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00548378$

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

From (5.4b), TBDY:  $\phi_u = 0.00548378$

we (5.4c)  $= 0.00245962$

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.09380979$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

AnoConf = 54733.333 is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh,min = \text{Min}(psh,x, psh,y) = 0.00283171$

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

---

$psh,x ((5.4d), TBDY) = Lstir \cdot Astir / (Asec \cdot s) = 0.00283171$   
 $Lstir$  (Length of stirrups along Y) = 1060.00  
 $Astir$  (stirrups area) = 78.53982  
 $Asec$  (section area) = 140000.00

---

$psh,y ((5.4d), TBDY) = Lstir \cdot Astir / (Asec \cdot s) = 0.00283171$   
 $Lstir$  (Length of stirrups along X) = 1060.00  
 $Astir$  (stirrups area) = 78.53982  
 $Asec$  (section area) = 140000.00

---

$s = 210.00$   
 $fywe = 555.55$   
 $fce = 18.00$   
From ((5.A5), TBDY), TBDY:  $cc = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $y1 = 0.00231479$   
 $sh1 = 0.008$   
 $ft1 = 666.66$   
 $fy1 = 555.55$   
 $su1 = 0.032$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $lo/lou,min = lb/ld = 1.00$   
 $su1 = 0.4 \cdot esu1\_nominal ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs1 = fs = 555.55$   
with  $Es1 = Es = 200000.00$   
 $y2 = 0.00231479$   
 $sh2 = 0.008$   
 $ft2 = 666.66$   
 $fy2 = 555.55$   
 $su2 = 0.032$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $lo/lou,min = lb/lb,min = 1.00$   
 $su2 = 0.4 \cdot esu2\_nominal ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs2 = fs = 555.55$   
with  $Es2 = Es = 200000.00$   
 $yv = 0.00231479$   
 $shv = 0.008$   
 $ftv = 666.66$   
 $fyv = 555.55$   
 $suv = 0.032$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $lo/lou,min = lb/ld = 1.00$   
 $suv = 0.4 \cdot esuv\_nominal ((5.5), TBDY) = 0.032$   
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.66229413
2 = Asl,com/(b*d)*(fs2/fc) = 0.31447059
v = Asl,mid/(b*d)*(fsv/fc) = 0.58605883
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is not satisfied
--->
cu (4.11) = 0.80684338
MRc (4.18) = 2.8814E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N1, N2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
--->
v* < v*sc - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
--->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
--->
*cu (4.11) = 0.98280667
MRo (4.18) = 1.3661E+008
MRo < 0.8*MRc
--->
u = cu (unconfined full section) = 1.6699237E-005
Mu = MRc
-----

Calculation of ratio lb/d
-----
Adequate Lap Length: lb/d >= 1
-----
-----
-----
Calculation of Mu1-

```

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

$$u = 1.0666733E-005$$

$$\mu = 3.9531E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.42649604$$

$$N = 1.4060E+006$$

$$f_c = 18.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00548378$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.00548378$$

$$\phi_{ue} (5.4c) = 0.00245962$$

$$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00283171$$

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

$$\phi_{sh,x} ((5.4d), \text{TBDY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$\phi_{sh,y} ((5.4d), \text{TBDY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along X}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 18.00$$

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

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_1_{nominal} ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_1_{nominal} = 0.08,$$

For calculation of  $esu_1_{nominal}$  and  $y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

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

$$\text{with } fs_1 = fs = 555.55$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00231479$$

```

sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
    using (30) in Biskinis/Fardis (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 = 1.00
    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 = 555.55
    with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (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 = 1.00
    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 = 555.55
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu

```

```

---->
Subcase: Rupture of tension steel
---->
 $v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied
---->
 $v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
 $v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied
---->
 $v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied
---->
 $\epsilon_{cu}$  (4.11) = 0.4973444
MRo (4.18) = 3.9531E+008
---->
 $u = \epsilon_{cu}$  (4.2) = 1.0666733E-005
Mu = MRo
-----

Calculation of ratio lb/d
-----
Adequate Lap Length: lb/d >= 1
-----
-----
-----
Calculation of Mu2+
-----
-----
-----
Calculation of ultimate curvature  $\epsilon_u$  according to 4.1, Biskinis/Fardis 2013:
 $\epsilon_u = 1.6699237E-005$ 
Mu = 2.8814E+008
-----
with full section properties:
b = 200.00
d = 407.00
d' = 43.00
v = 0.95961609
N = 1.4060E+006
fc = 18.00
 $\epsilon_{co}$  (5A.5, TBDY) = 0.002
Final value of  $\epsilon_{cu}$ :  $\epsilon_{cu}^* = \text{shear\_factor} * \text{Max}(\epsilon_{cu}, \epsilon_{cc}) = 0.00548378$ 
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY:  $\epsilon_{cu} = 0.00548378$ 
we (5.4c) = 0.00245962
ase =  $\text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$ 
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,max = 89600.00 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 perimeter hoops.
Aconf,min = 21600.00 is the confined core area at midway between the levels of hoops and
is calculated by reducing all the dimensions of the area Aconf,max by a length
equal to half the clear spacing between hoops.
AnoConf = 54733.333 is the unconfined core area which is equal to  $b^2/6$  as defined at (A.2).
psh,min = Min(psh,x , psh,y) = 0.00283171
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without
earthquake detailing (90° closed stirrups)
-----
psh,x ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$ 
Lstir (Length of stirrups along Y) = 1060.00
Astir (stirrups area) = 78.53982

```



Asec (section area) = 140000.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00283171

Lstir (Length of stirrups along X) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

s = 210.00

fywe = 555.55

fce = 18.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

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

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

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

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

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

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

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

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

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

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

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

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

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

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

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.66229413

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.31447059

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.58605883

and confined core properties:

b = 140.00

d = 377.00

```

d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
  c = confinement factor = 1.00
  1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
  2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
  v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
  cu (4.11) = 0.80684338
MRc (4.18) = 2.8814E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
  - b, d, d' replaced by geometric parameters of the core: bo, do, d'o
  - N, 1, 2, v normalised to bo*do, instead of b*d
  - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
  *cu (4.11) = 0.98280667
MRo (4.18) = 1.3661E+008
MRo < 0.8*MRc
---->
  u = cu (unconfined full section) = 1.6699237E-005
Mu = MRc
-----

Calculation of ratio lb/d
-----

Adequate Lap Length: lb/d >= 1
-----

Calculation of Mu2-
-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
  u = 1.0666733E-005
Mu = 3.9531E+008
-----

with full section properties:

```

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.42649604$   
 $N = 1.4060E+006$   
 $f_c = 18.00$   
 $\phi (5A.5, \text{TB DY}) = 0.002$   
 Final value of  $\phi$ :  $\phi^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00548378$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TB DY:  $\phi_u = 0.00548378$   
 $\phi_c (5.4c) = 0.00245962$   
 $\phi_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$   
 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.  
 $A_{conf,max} = 89600.00$  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 perimeter hoops.  
 $A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.  
 $A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i d_i / 6$  as defined at (A.2).  
 $\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00283171$   
 Expression ((5.4d), TB DY) for  $\phi_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

---

$\phi_{sh,x} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$   
 $L_{stir}$  (Length of stirrups along Y) = 1060.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 140000.00

---

$\phi_{sh,y} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$   
 $L_{stir}$  (Length of stirrups along X) = 1060.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 140000.00

---

$s = 210.00$   
 $f_{ywe} = 555.55$   
 $f_{ce} = 18.00$   
 From ((5.A5), TB DY), TB DY:  $\phi_c = 0.002$   
 $\phi_c$  = confinement factor = 1.00  
 $y_1 = 0.00231479$   
 $sh_1 = 0.008$   
 $ft_1 = 666.66$   
 $fy_1 = 555.55$   
 $su_1 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $l_o / l_{ou,min} = l_b / l_d = 1.00$   
 $su_1 = 0.4 * esu_1_{nominal} ((5.5), \text{TB DY}) = 0.032$   
 From table 5A.1, TB DY:  $esu_1_{nominal} = 0.08$ ,  
 For calculation of  $esu_1_{nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fs_1 = f_s / 1.2$ , from table 5.1, TB DY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_1 = f_s = 555.55$   
 with  $Es_1 = E_s = 200000.00$   
 $y_2 = 0.00231479$   
 $sh_2 = 0.008$   
 $ft_2 = 666.66$   
 $fy_2 = 555.55$   
 $su_2 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $l_o / l_{ou,min} = l_b / l_{b,min} = 1.00$

```

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 = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
--->
v* < v*sc - LHS eq.(4.5) is not satisfied
--->
Subcase rejected

```

--->  
New Subcase: Failure of compression zone

--->  
 $v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied

--->  
 $v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied

--->  
 $\mu_{cu}(4.11) = 0.4973444$   
 $M_{Ro}(4.18) = 3.9531E+008$

--->  
 $u = \mu_{cu}(4.2) = 1.0666733E-005$   
 $\mu_u = M_{Ro}$

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

-----  
Adequate Lap Length:  $l_b/l_d \geq 1$

-----  
Calculation of Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 229892.529$

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 229892.529$

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

$V_{Col0} = 229892.529$

$knl = 1$  (zero step-static loading)

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

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

$f'_c = 18.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.2440E+008$

$\mu_u = 3.7569140E-005$

$d = 0.8 * h = 360.00$

$N_u = 1.4060E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$

where:

$V_{s1} = 0.00$  is calculated for section web, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

$V_{s1}$  is multiplied by  $Col1 = 0.00$

$s/d = 1.3125$

$V_{s2} = 119678.523$  is calculated for section flange, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

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

$s/d = 0.58333333$

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

From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$

$bw = 200.00$

-----  
Calculation of Shear Strength at edge 2,  $V_{r2} = 229892.529$

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

$V_{Col0} = 229892.529$

$knl = 1$  (zero step-static loading)

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

= 1 (normal-weight concrete)  
 $f_c' = 18.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 1.0841E+008$   
 $V_u = 3.7569140E-005$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 1.4060E+006$   
 $A_g = 90000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$   
 where:  
 $V_{s1} = 0.00$  is calculated for section web, with:  
 $d = 160.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 210.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.00$   
 $s/d = 1.3125$   
 $V_{s2} = 119678.523$  is calculated for section flange, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 210.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.58333333$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$   
 $b_w = 200.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
 At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1  
 At local axis: 2  
 Integration Section: (b)  
 Section Type: rclcs

#### 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:  
 Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 18.00$   
 Existing material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
 Concrete Elasticity,  $E_c = 19940.411$   
 Steel Elasticity,  $E_s = 200000.00$   
 Max Height,  $H_{max} = 450.00$   
 Min Height,  $H_{min} = 200.00$   
 Max Width,  $W_{max} = 450.00$   
 Min Width,  $W_{min} = 200.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Smooth Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_b/l_d \geq 1$ )  
 No FRP Wrapping

#### Stepwise Properties

Bending Moment,  $M = 1.1243\text{E}+008$   
 Shear Force,  $V2 = -87433.392$   
 Shear Force,  $V3 = 5.71847$   
 Axial Force,  $F = -1.4055\text{E}+006$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $Asl_t = 829.3805$   
   -Compression:  $Asl_c = 3292.389$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $Asl_{ten} = 829.3805$   
   -Compression:  $Asl_{com} = 1746.726$   
   -Middle:  $Asl_{mid} = 1545.664$   
 Mean Diameter of Tension Reinforcement,  $DbL = 18.66667$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = \frac{u}{y + p} = 0.03467193$   
 $u = y + p = 0.03467193$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.02547133$  ((4.29), Biskinis Phd))  
 $M_y = 3.8889\text{E}+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) =  $6000.00$   
 From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} * E_c * I_g = 3.0536\text{E}+013$   
   factor =  $0.70$   
    $A_g = 140000.00$   
    $f_c' = 18.00$   
    $N = 1.4055\text{E}+006$   
    $E_c * I_g = 4.3623\text{E}+013$

Calculation of Yielding Moment  $M_y$

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

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

flange width,  $b = 450.00$   
 web width,  $b_w = 200.00$   
 flange thickness,  $t = 200.00$

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 9.8163407\text{E}-006$   
 with  $f_y = 444.44$   
    $d = 407.00$   
    $y = 0.44378959$   
    $A = 0.03977181$   
    $B = 0.02746844$   
   with  $p_t = 0.00283171$   
      $p_c = 0.00953713$   
      $p_v = 0.00843933$   
      $N = 1.4055\text{E}+006$   
      $b = 450.00$   
      $" = 0.10565111$   
 $y_{comp} = 8.6105988\text{E}-006$   
 with  $f_c = 18.00$   
    $E_c = 19940.411$   
    $y = 0.46364239$   
    $A = -0.00111008$   
    $B = 0.01020151$   
   with  $E_s = 200000.00$   
 CONFIRMATION:  $y = 0.46364239 < t/d$

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

- Calculation of  $p$  -

From table 10-8:  $p = 0.0092006$

with:

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

shear control ratio  $V_{yE}/V_{ColOE} = 1.14637$

$d = 407.00$

$s = 150.00$

$t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.00283171$

$A_v = 78.53982$ , is the area of every stirrup

$L_{stir} = 1060.00$ , is the total Length of all stirrups parallel to loading (shear) direction

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

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

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

$NUD = 1.4055E+006$

$A_g = 140000.00$

$f_{cE} = 18.00$

$f_{yE} = f_{yIE} = 444.44$

$p_l = \text{Area\_Tot\_Long\_Rein}/(b*d) = 0.02250488$

$b = 450.00$

$d = 407.00$

$f_{cE} = 18.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 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 50 and 51)

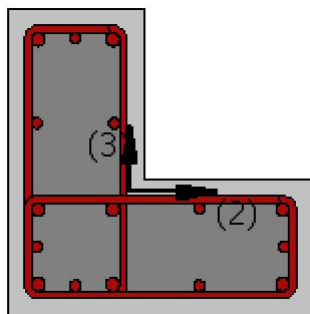
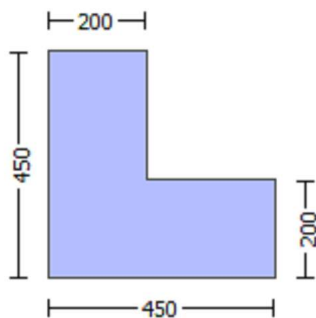
Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: End

Local Axis: (3)





Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcls

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:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 12.00$

Existing material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$

Concrete Elasticity,  $E_c = 19940.411$

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).

Existing material: Concrete Strength,  $f_c = f_{cm} = 18.00$

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

#####

Max Height,  $H_{max} = 450.00$

Min Height,  $H_{min} = 200.00$

Max Width,  $W_{max} = 450.00$

Min Width,  $W_{min} = 200.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_o/l_{ou,min} = l_b/l_d \geq 1$ )

No FRP Wrapping

Stepwise Properties

EDGE -A-

Bending Moment,  $M_a = -1.8423E+008$

Shear Force,  $V_a = -5.71847$

EDGE -B-

Bending Moment,  $M_b = 1.1243E+008$

Shear Force,  $V_b = 5.71847$

BOTH EDGES

Axial Force,  $F = -1.4055E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 829.3805$

-Compression:  $As_c = 3292.389$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

-Compression:  $A_{sl,com} = 1746.726$

-Middle:  $A_{sl,mid} = 1545.664$

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

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = V_n = 206190.061$

$V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{CoI0} = 206190.061$

$V_{CoI} = 206190.061$

$k_n = 1.00$

$displacement\_ductility\_demand = 0.16700315$

NOTE: In expression (10-3) ' $V_s$ ' is replaced by ' $V_s + f \cdot V_f$ '

where  $V_f$  is the contribution of FRPs ((11.3), ACI 440).

$= 1$  (normal-weight concrete)

$f_c' = 12.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$M_u = 1.1243E+008$

$V_u = 5.71847$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.4055E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 107711.748$

where:

$V_{s1} = 107711.748$  is calculated for section web, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 210.00$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$s/d = 0.58333333$

$V_{s2} = 0.00$  is calculated for section flange, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 210.00$

$V_{s2}$  is multiplied by  $Col2 = 0.00$

$s/d = 1.3125$

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

From (11-11), ACI 440:  $V_s + V_f \leq 165687.55$

$b_w = 200.00$

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

- Calculation of  $\phi / y$  for END B -

for rotation axis 2 and integ. section (b)

From analysis, chord rotation  $\theta = 0.00425379$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.02547133$  ((4.29), Biskinis Phd))

$M_y = 3.8889E+008$

$L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) =  $6000.00$

From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 3.0536E+013$

$factor = 0.70$

$A_g = 140000.00$

$f_c' = 18.00$

$N = 1.4055E+006$

$E_c \cdot I_g = 4.3623E+013$

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,  $b = 450.00$

web width,  $b_w = 200.00$

flange thickness,  $t = 200.00$

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

$y_{\text{ten}} = 9.8163407\text{E-}006$

with  $f_y = 444.44$

$d = 407.00$

$y = 0.44378959$

$A = 0.03977181$

$B = 0.02746844$

with  $p_t = 0.00452842$

$p_c = 0.00953713$

$p_v = 0.00843933$

$N = 1.4055\text{E+}006$

$b = 450.00$

" = 0.10565111

$y_{\text{comp}} = 8.6105988\text{E-}006$

with  $f_c = 18.00$

$E_c = 19940.411$

$y = 0.46364239$

$A = -0.00111008$

$B = 0.01020151$

with  $E_s = 200000.00$

CONFIRMATION:  $y = 0.46364239 < t/d$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

## Calculation No. 16

column C1, Floor 1

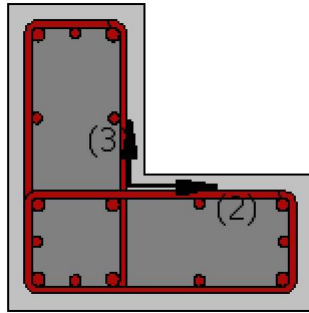
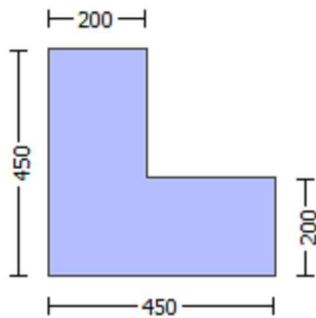
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\theta$  )

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rccls

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 18.00$

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

Concrete Elasticity,  $E_c = 19940.411$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height,  $H_{max} = 450.00$

Min Height,  $H_{min} = 200.00$

Max Width,  $W_{max} = 450.00$

Min Width,  $W_{min} = 200.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length,  $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_o/l_{ou, min} \geq 1$ )

No FRP Wrapping

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = -8.8389216E-005$

EDGE -B-

Shear Force,  $V_b = 8.8389216E-005$

BOTH EDGES

Axial Force,  $F = -1.4060E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 829.3805$

-Compression:  $As_c = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

-Compression:  $As_{c, com} = 1746.726$

-Middle:  $As_{l, mid} = 1545.664$

Calculation of Shear Capacity ratio ,  $V_e/V_r = 1.14637$

Member Controlled by Shear ( $V_e/V_r > 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 263541.358$   
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 3.9531\text{E}+008$

$\mu_{1+} = 3.9531\text{E}+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{1-} = 2.8814\text{E}+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 3.9531\text{E}+008$

$\mu_{2+} = 3.9531\text{E}+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 2.8814\text{E}+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $\mu_{1+}$

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

$\mu = 1.0666733\text{E}-005$

$M_u = 3.9531\text{E}+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.42649604$

$N = 1.4060\text{E}+006$

$f_c = 18.00$

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

Final value of  $\phi_{cu}$ :  $\phi_{cu}^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_c) = 0.00548378$

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

From (5.4b), TBDY:  $\phi_{cu} = 0.00548378$

$\phi_{we}$  (5.4c) = 0.00245962

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.09380979$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\phi_{psh,min} = \text{Min}(\phi_{psh,x}, \phi_{psh,y}) = 0.00283171$

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

$\phi_{psh,x}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along Y) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$\phi_{psh,y}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along X) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$s = 210.00$

$f_{ywe} = 555.55$

```

fce = 18.00
From ((5A.5), TBDY), TBDY: cc = 0.002
c = confinement factor = 1.00
y1 = 0.00231479
sh1 = 0.008
ft1 = 666.66
fy1 = 555.55
su1 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
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 = 555.55
with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
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 = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb,min)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)

```

```

---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
'satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N1, N2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.4973444
MRo (4.18) = 3.9531E+008
---->
u = cu (4.2) = 1.0666733E-005
Mu = MRo

```

-----

Calculation of ratio lb/d

-----

Adequate Lap Length: lb/d >= 1

-----

-----

-----

Calculation of Mu1-

-----

-----

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

u = 1.6699237E-005

Mu = 2.8814E+008

-----

with full section properties:

b = 200.00

d = 407.00

d' = 43.00

v = 0.95961609

N = 1.4060E+006

f<sub>c</sub> = 18.00

c<sub>o</sub> (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, c<sub>c</sub>) = 0.00548378

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

From (5.4b), TBDY: cu = 0.00548378

$$w_e (5.4c) = 0.00245962$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$$

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.

$A_{conf,max}$  = 89600.00 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 perimeter hoops.

$A_{conf,min}$  = 21600.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf}$  = 54733.333 is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00283171$$

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

$$p_{sh,x} ((5.4d), \text{TBDY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$p_{sh,y} ((5.4d), \text{TBDY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} (\text{Length of stirrups along X}) = 1060.00$$

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

$$A_{sec} (\text{section area}) = 140000.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 18.00$$

$$\text{From } ((5.A5), \text{TBDY}), \text{TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

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

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.

$$\text{with } fs_1 = fs = 555.55$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

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

$$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$$

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

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

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

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

$$\text{with } fs_2 = fs = 555.55$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$



```

fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (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 = 1.00
    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 = 555.55
    with Esv = Es = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.66229413
    2 = Asl,com/(b*d)*(fs2/fc) = 0.31447059
    v = Asl,mid/(b*d)*(fsv/fc) = 0.58605883
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
    2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
    v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
    cu (4.11) = 0.80684338
    MRc (4.18) = 2.8814E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
    - b, d, d' replaced by geometric parameters of the core: bo, do, d'o
    - N, 1, 2, v normalised to bo*do, instead of b*d
    - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
    *cu (4.11) = 0.98280667
    MRo (4.18) = 1.3661E+008
    MRo < 0.8*MRc

```

--->

u = cu (unconfined full section) = 1.6699237E-005  
Mu = MRc

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

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

u = 1.0666733E-005  
Mu = 3.9531E+008

with full section properties:

b = 450.00  
d = 407.00  
d' = 43.00  
v = 0.42649604  
N = 1.4060E+006

fc = 18.00  
co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.00548378

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

From (5.4b), TBDY: cu = 0.00548378

we (5.4c) = 0.00245962

ase = Max(((Aconf,max-AnoConf)/Aconf,max)\*(Aconf,min/Aconf,max),0) = 0.09380979

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,max = 89600.00 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 perimeter hoops.

Aconf,min = 21600.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 54733.333 is the unconfined core area which is equal to bi2/6 as defined at (A.2).

psh,min = Min(psh,x, psh,y) = 0.00283171

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

psh,x ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00283171

Lstir (Length of stirrups along Y) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00283171

Lstir (Length of stirrups along X) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

s = 210.00

fywe = 555.55

fce = 18.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

```

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.
with fs1 = fs = 555.55
with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
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 = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->

```

$v < s, y1$  - LHS eq.(4.7) is not satisfied

---->

$v < v_c, y1$  - RHS eq.(4.6) is satisfied

---->

$\epsilon_{cu}$  (4.10) = 0.40653976

$M_{Rc}$  (4.17) = 4.7962E+008

---->

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- $b, d, d'$  replaced by geometric parameters of the core:  $b_o, d_o, d'_o$
- $N, 1, 2, v$  normalised to  $b_o * d_o$ , instead of  $b * d$
- - parameters of confined concrete,  $f_{cc}, \epsilon_{cc}$ , used in lieu of  $f_c, \epsilon_{cu}$

---->

Subcase: Rupture of tension steel

---->

$v^* < v^* s, y2$  - LHS eq.(4.5) is not satisfied

---->

$v^* < v^* s, c$  - LHS eq.(4.5) is not satisfied

---->

Subcase rejected

---->

New Subcase: Failure of compression zone

---->

$v^* < v^* c, y2$  - LHS eq.(4.6) is not satisfied

---->

$v^* < v^* c, y1$  - RHS eq.(4.6) is not satisfied

---->

$\epsilon^*_{cu}$  (4.11) = 0.4973444

$M_{Ro}$  (4.18) = 3.9531E+008

---->

$u = \epsilon_{cu}$  (4.2) = 1.0666733E-005

$M_u = M_{Ro}$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

Calculation of  $M_{u2}$

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

$u = 1.6699237E-005$

$M_u = 2.8814E+008$

with full section properties:

$b = 200.00$

$d = 407.00$

$d' = 43.00$

$v = 0.95961609$

$N = 1.4060E+006$

$f_c = 18.00$

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

Final value of  $\epsilon_{cu}$ :  $\epsilon_{cu}^* = \text{shear\_factor} * \text{Max}(\epsilon_{cu}, \epsilon_{cc}) = 0.00548378$

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

From (5.4b), TBDY:  $\epsilon_{cu} = 0.00548378$

we (5.4c) = 0.00245962

$\epsilon_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.  
 $A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00283171$

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

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00283171$

$L_{stir}$  (Length of stirrups along Y) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00283171$

$L_{stir}$  (Length of stirrups along X) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$s = 210.00$

$f_{ywe} = 555.55$

$f_{ce} = 18.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.002$

$c = \text{confinement factor} = 1.00$

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

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

$lo/lou,min = lb/ld = 1.00$

$su_1 = 0.4 \cdot esu1\_nominal \text{ ((5.5), TBDY)} = 0.032$

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

For calculation of  $esu1\_nominal$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

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

with  $fs_1 = fs = 555.55$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

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

$lo/lou,min = lb/lb,min = 1.00$

$su_2 = 0.4 \cdot esu2\_nominal \text{ ((5.5), TBDY)} = 0.032$

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

For calculation of  $esu2\_nominal$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.

$y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_2 = fs = 555.55$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$suv = 0.032$

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

$lo/lou,min = lb/ld = 1.00$

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

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

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY  
For calculation of  $e_{suv\_nominal}$  and  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $f_{yv}$ , it is considered  
characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1$ ,  $ft_1$ ,  $f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $f_{sv} = f_s = 555.55$   
with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.66229413$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.31447059$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.58605883$   
and confined core properties:  
 $b = 140.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} \text{ (5A.2, TBDY)} = 18.00$   
 $cc \text{ (5A.5, TBDY)} = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 1.02142$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.48499254$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.90384974$   
Case/Assumption: Unconfined full section - Steel rupture  
' does not satisfy Eq. (4.3)  
--->  
 $v < v_{s,c}$  - RHS eq.(4.5) is not satisfied  
--->  
Case/Assumption Rejected.  
--->  
New Case/Assumption: Unconfined full section - Spalling of concrete cover  
' satisfies Eq. (4.4)  
--->  
 $v < s_{y1}$  - LHS eq.(4.7) is not satisfied  
--->  
 $v < v_{c,y1}$  - RHS eq.(4.6) is not satisfied  
--->  
 $c_u \text{ (4.11)} = 0.80684338$   
 $M_{Rc} \text{ (4.18)} = 2.8814E+008$   
--->  
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover  
In expressions below, the following modifications have been made  
-  $b$ ,  $d$ ,  $d'$  replaced by geometric parameters of the core:  $b_o$ ,  $d_o$ ,  $d'_o$   
-  $N$ ,  $1$ ,  $2$ ,  $v$  normalised to  $b_o \cdot d_o$ , instead of  $b \cdot d$   
-  $f_{cc}$ ,  $cc$ , used in lieu of  $f_c$ ,  $e_{cu}$   
--->  
Subcase: Rupture of tension steel  
--->  
 $v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied  
--->  
 $v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied  
--->  
Subcase rejected  
--->  
New Subcase: Failure of compression zone  
--->  
 $v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied  
--->  
 $v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied  
--->  
 $*c_u \text{ (4.11)} = 0.98280667$   
 $M_{Ro} \text{ (4.18)} = 1.3661E+008$   
 $M_{Ro} < 0.8 \cdot M_{Rc}$   
--->  
 $u = c_u \text{ (unconfined full section)} = 1.6699237E-005$   
 $\mu = M_{Rc}$

---

Calculation of ratio  $l_b/l_d$

---

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 229892.529$

Calculation of Shear Strength at edge 1,  $V_{r1} = 229892.529$

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

$V_{\text{ColO}} = 229892.529$

$k_n l = 1$  (zero step-static loading)

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

$= 1$  (normal-weight concrete)

$f'_c = 18.00$ , but  $f'_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.2877\text{E}+008$

$V_u = 8.8389216\text{E}-005$

$d = 0.8 * h = 360.00$

$N_u = 1.4060\text{E}+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$

where:

$V_{s1} = 119678.523$  is calculated for section web, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

$V_{s1}$  is multiplied by  $\text{Col1} = 1.00$

$s/d = 0.58333333$

$V_{s2} = 0.00$  is calculated for section flange, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

$V_{s2}$  is multiplied by  $\text{Col2} = 0.00$

$s/d = 1.3125$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 0.00$

From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$

$b_w = 200.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 229892.529$

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

$V_{\text{ColO}} = 229892.529$

$k_n l = 1$  (zero step-static loading)

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

$= 1$  (normal-weight concrete)

$f'_c = 18.00$ , but  $f'_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.1237\text{E}+008$

$V_u = 8.8389216\text{E}-005$

$d = 0.8 * h = 360.00$

$N_u = 1.4060\text{E}+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$

where:

$V_{s1} = 119678.523$  is calculated for section web, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

$V_{s1}$  is multiplied by  $\text{Col1} = 1.00$

```

s/d = 0.58333333
Vs2 = 0.00 is calculated for section flange, with:
d = 160.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs2 is multiplied by Col2 = 0.00
s/d = 1.3125
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 202924.977
bw = 200.00
-----

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At local axis: 3
-----

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rdcs

Constant Properties
-----
Knowledge Factor, = 1.00
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Secondary Member: Concrete Strength, fc = fcm = 18.00
Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44
Concrete Elasticity, Ec = 19940.411
Steel Elasticity, Es = 200000.00
#####
Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, fs = 1.25*fsm = 555.55
#####
Max Height, Hmax = 450.00
Min Height, Hmin = 200.00
Max Width, Wmax = 450.00
Min Width, Wmin = 200.00
Cover Thickness, c = 25.00
Mean Confinement Factor overall section = 1.00
Element Length, L = 3000.00
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length (lo/lou, min >= 1)
No FRP Wrapping
-----

Stepwise Properties
-----
At local axis: 2
EDGE -A-
Shear Force, Va = 3.7569140E-005
EDGE -B-
Shear Force, Vb = -3.7569140E-005
BOTH EDGES
Axial Force, F = -1.4060E+006
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 829.3805
-Compression: Aslc = 3091.327
Longitudinal Reinforcement Area Distribution (in 3 divisions)

```



-Tension:  $A_{sl,ten} = 1746.726$   
 -Compression:  $A_{sl,com} = 829.3805$   
 -Middle:  $A_{sl,mid} = 1545.664$

Calculation of Shear Capacity ratio ,  $V_e/V_r = 1.14637$

Member Controlled by Shear ( $V_e/V_r > 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 263541.358$   
 with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 3.9531E+008$

$M_{u1+} = 2.8814E+008$ , 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

$M_{u1-} = 3.9531E+008$ , 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 3.9531E+008$

$M_{u2+} = 2.8814E+008$ , 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

$M_{u2-} = 3.9531E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $M_{u1+}$

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

$\phi_u = 1.6699237E-005$

$M_u = 2.8814E+008$

with full section properties:

$b = 200.00$

$d = 407.00$

$d' = 43.00$

$v = 0.95961609$

$N = 1.4060E+006$

$f_c = 18.00$

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

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00548378$

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

From (5.4b), TBDY:  $\phi_u = 0.00548378$

$\phi_{ue}$  (5.4c) = 0.00245962

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.09380979$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\phi_{psh,min} = \text{Min}(\phi_{psh,x}, \phi_{psh,y}) = 0.00283171$

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

$\phi_{psh,x}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along Y) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

$\phi_{psh,y}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along X) = 1060.00

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

Asec (section area) = 140000.00

s = 210.00

fywe = 555.55

fce = 18.00

From ((5A.5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

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

lo/lou,min = lb/lb = 1.00

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 = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

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

lo/lou,min = lb/lb,min = 1.00

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 = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

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

lo/lou,min = lb/lb = 1.00

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 = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.66229413

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.31447059

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.58605883

and confined core properties:

b = 140.00

d = 377.00

d' = 13.00

fcc (5A.2, TBDY) = 18.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 1.02142

```

2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.80684338
MRc (4.18) = 2.8814E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.98280667
MRo (4.18) = 1.3661E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 1.6699237E-005
Mu = MRc
-----

Calculation of ratio lb/ld
-----
Adequate Lap Length: lb/ld >= 1
-----

Calculation of Mu1-
-----

-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.0666733E-005
Mu = 3.9531E+008
-----

with full section properties:
b = 450.00
d = 407.00
d' = 43.00
v = 0.42649604
N = 1.4060E+006

```

$f_c = 18.00$   
 $\alpha (5A.5, \text{TBDY}) = 0.002$   
 Final value of  $\alpha$ :  $\alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.00548378$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\alpha = 0.00548378$   
 $\alpha_e (5.4c) = 0.00245962$   
 $\alpha_{se} = \text{Max}(((\alpha_{conf,max} - \alpha_{noConf}) / \alpha_{conf,max}) * (\alpha_{conf,min} / \alpha_{conf,max}), 0) = 0.09380979$   
 The definitions of  $\alpha_{noConf}$ ,  $\alpha_{conf,min}$  and  $\alpha_{conf,max}$  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.  
 $\alpha_{conf,max} = 89600.00$  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 perimeter hoops.  
 $\alpha_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $\alpha_{conf,max}$  by a length equal to half the clear spacing between hoops.  
 $\alpha_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $\alpha_{sh,min} = \text{Min}(\alpha_{sh,x}, \alpha_{sh,y}) = 0.00283171$   
 Expression ((5.4d), TBDY) for  $\alpha_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\alpha_{sh,x} ((5.4d), \text{TBDY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$   
 $L_{stir}$  (Length of stirrups along Y) = 1060.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 140000.00

$\alpha_{sh,y} ((5.4d), \text{TBDY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$   
 $L_{stir}$  (Length of stirrups along X) = 1060.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 140000.00

$s = 210.00$   
 $f_{ywe} = 555.55$   
 $f_{ce} = 18.00$

From ((5.A5), TBDY), TBDY:  $\alpha_c = 0.002$   
 $\alpha_c$  = confinement factor = 1.00

$y_1 = 0.00231479$   
 $\alpha_{sh1} = 0.008$   
 $f_{t1} = 666.66$   
 $f_{y1} = 555.55$   
 $\alpha_{su1} = 0.032$

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

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

From table 5A.1, TBDY:  $\alpha_{su1\_nominal} = 0.08$ ,

For calculation of  $\alpha_{su1\_nominal}$  and  $y_1, \alpha_{sh1}, f_{t1}, f_{y1}$ , it is considered characteristic value  $f_{sy1} = f_s / 1.2$ , from table 5.1, TBDY.

$y_1, \alpha_{sh1}, f_{t1}, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (\alpha_{lb/l_d})^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{s1} = f_s = 555.55$   
 with  $E_{s1} = E_s = 200000.00$

$y_2 = 0.00231479$   
 $\alpha_{sh2} = 0.008$   
 $f_{t2} = 666.66$   
 $f_{y2} = 555.55$   
 $\alpha_{su2} = 0.032$

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

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

From table 5A.1, TBDY:  $\alpha_{su2\_nominal} = 0.08$ ,

For calculation of  $\alpha_{su2\_nominal}$  and  $y_2, \alpha_{sh2}, f_{t2}, f_{y2}$ , it is considered characteristic value  $f_{sy2} = f_s / 1.2$ , from table 5.1, TBDY.

$y_1, \alpha_{sh1}, f_{t1}, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (\alpha_{lb/l_d})^{2/3})$ , from 10.3.5, ASCE 41-17.

```

with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < s,y1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
--->
v* < v*s,c - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
--->

```

$v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied

--->

$$*cu(4.11) = 0.4973444$$

$$MRo(4.18) = 3.9531E+008$$

--->

$$u = cu(4.2) = 1.0666733E-005$$

$$Mu = MRo$$

Calculation of ratio  $lb/ld$

Adequate Lap Length:  $lb/ld \geq 1$

Calculation of  $Mu_{2+}$

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

$$u = 1.6699237E-005$$

$$Mu = 2.8814E+008$$

with full section properties:

$$b = 200.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.95961609$$

$$N = 1.4060E+006$$

$$fc = 18.00$$

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

$$\text{Final value of } cu: cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00548378$$

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

$$\text{From (5.4b), TBDY: } cu = 0.00548378$$

$$we(5.4c) = 0.00245962$$

$$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.09380979$$

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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00283171$$

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

$$psh_x((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1060.00$$

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

$$A_{sec} \text{ (section area)} = 140000.00$$

$$psh_y((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1060.00$$

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

$$A_{sec} \text{ (section area)} = 140000.00$$

$$s = 210.00$$

$$fy_{we} = 555.55$$

$$f_{ce} = 18.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y1 = 0.00231479$$

```

sh1 = 0.008
ft1 = 666.66
fy1 = 555.55
su1 = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 1.00
    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 = 555.55
    with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 1.00
    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 = 555.55
    with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 1.00
    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 = 555.55
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.66229413
2 = Asl,com/(b*d)*(fs2/fc) = 0.31447059
v = Asl,mid/(b*d)*(fsv/fc) = 0.58605883
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 1.02142
    2 = Asl,com/(b*d)*(fs2/fc) = 0.48499254
    v = Asl,mid/(b*d)*(fsv/fc) = 0.90384974
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.

```

```

---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
'satisfies Eq. (4.4)
---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.80684338
MRc (4.18) = 2.8814E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.98280667
MRo (4.18) = 1.3661E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 1.6699237E-005
Mu = MRc
-----

Calculation of ratio lb/d
-----
Adequate Lap Length: lb/d >= 1
-----
-----
-----
Calculation of Mu2-
-----
-----
-----
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.0666733E-005
Mu = 3.9531E+008
-----
with full section properties:
b = 450.00
d = 407.00
d' = 43.00
v = 0.42649604
N = 1.4060E+006
fc = 18.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.00548378
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.00548378
we (5.4c) = 0.00245962
ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.09380979
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.

$A_{conf,max} = 89600.00$  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 perimeter hoops.

$A_{conf,min} = 21600.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00283171$

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

-----  
 $p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along Y) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

-----  
 $p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00283171$

$L_{stir}$  (Length of stirrups along X) = 1060.00

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

$A_{sec}$  (section area) = 140000.00

-----  
 $s = 210.00$

$f_{ywe} = 555.55$

$f_{ce} = 18.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.002$

$c$  = confinement factor = 1.00

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

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

$l_o/l_{ou,min} = l_b/l_d = 1.00$

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

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

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

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

with  $fs_1 = fs = 555.55$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

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

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$

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

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

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

$y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_2 = fs = 555.55$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$su_v = 0.032$

using (30) in Biskinis/Fardis (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 = 1.00
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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.13976471
2 = Asl,com/(b*d)*(fs2/fc) = 0.29435295
v = Asl,mid/(b*d)*(fsv/fc) = 0.26047059
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 18.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.17409989
2 = Asl,com/(b*d)*(fs2/fc) = 0.36666491
v = Asl,mid/(b*d)*(fsv/fc) = 0.32445888
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.40653976
MRc (4.17) = 4.7962E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.4973444
MRo (4.18) = 3.9531E+008
---->
u = cu (4.2) = 1.0666733E-005
Mu = MRo
-----

```

Calculation of ratio  $l_b/d$

Adequate Lap Length:  $l_b/d \geq 1$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 229892.529$

Calculation of Shear Strength at edge 1,  $V_{r1} = 229892.529$

$V_{r1} = V_{\text{Col}} \text{ ((10.3), ASCE 41-17)} = k_n l^* V_{\text{ColO}}$

$V_{\text{ColO}} = 229892.529$

$k_n l = 1$  (zero step-static loading)

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

$= 1$  (normal-weight concrete)

$f'_c = 18.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.2440\text{E}+008$

$\mu_u = 3.7569140\text{E}-005$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.4060\text{E}+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$

where:

$V_{s1} = 0.00$  is calculated for section web, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

$V_{s1}$  is multiplied by  $\text{Col1} = 0.00$

$s/d = 1.3125$

$V_{s2} = 119678.523$  is calculated for section flange, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

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

$s/d = 0.58333333$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 0.00$

From (11-11), ACI 440:  $V_s + V_f \leq 202924.977$

$b_w = 200.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 229892.529$

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

$V_{\text{ColO}} = 229892.529$

$k_n l = 1$  (zero step-static loading)

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

$= 1$  (normal-weight concrete)

$f'_c = 18.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.0841\text{E}+008$

$\mu_u = 3.7569140\text{E}-005$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.4060\text{E}+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 119678.523$

where:

$V_{s1} = 0.00$  is calculated for section web, with:

$d = 160.00$

Av = 157079.633

fy = 444.44

s = 210.00

Vs1 is multiplied by Col1 = 0.00

s/d = 1.3125

Vs2 = 119678.523 is calculated for section flange, with:

d = 360.00

Av = 157079.633

fy = 444.44

s = 210.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.583333333

Vf ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: Vs + Vf <= 202924.977

bw = 200.00

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1  
At local axis: 3

Integration Section: (b)

Section Type: rdcs

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:

Existing material of Secondary Member: Concrete Strength, fc = fcm = 18.00

Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44

Concrete Elasticity, Ec = 19940.411

Steel Elasticity, Es = 200000.00

Max Height, Hmax = 450.00

Min Height, Hmin = 200.00

Max Width, Wmax = 450.00

Min Width, Wmin = 200.00

Cover Thickness, c = 25.00

Element Length, L = 3000.00

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length (lb/ld >= 1)

No FRP Wrapping

Stepwise Properties

Bending Moment, M = 1.2593E+008

Shear Force, V2 = -87433.392

Shear Force, V3 = 5.71847

Axial Force, F = -1.4055E+006

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: Aslt = 829.3805

-Compression: Aslc = 3292.389

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: Asl,ten = 1746.726

-Compression: Asl,com = 829.3805

-Middle: Asl,mid = 1545.664

Mean Diameter of Tension Reinforcement, DbL = 17.71429

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $\phi_R = \phi_u = 0.01237458$   
 $\phi_u = \phi_y + \phi_p = 0.01237458$

- Calculation of  $\phi_y$  -

$\phi_y = (M_y * L_s / 3) / E_{eff} = 0.00317398$  ((4.29), Biskinis Phd))  
 $M_y = 2.0187E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 1440.333  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 3.0536E+013$   
factor = 0.70  
 $A_g = 140000.00$   
 $f_c' = 18.00$   
 $N = 1.4055E+006$   
 $E_c * I_g = 4.3623E+013$

Calculation of Yielding Moment  $M_y$

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

$\phi_y = \min(\phi_{y\_ten}, \phi_{y\_com})$   
 $\phi_{y\_ten} = 1.3705984E-005$   
with  $f_y = 444.44$   
 $d = 407.00$   
 $\phi_y = 0.60163744$   
 $A = 0.08948658$   
 $B = 0.07188293$   
with  $p_t = 0.00283171$   
 $p_c = 0.01018895$   
 $p_v = 0.0189885$   
 $N = 1.4055E+006$   
 $b = 200.00$   
 $\phi_y = 0.10565111$   
 $\phi_{y\_comp} = 4.7557658E-006$   
with  $f_c = 18.00$   
 $E_c = 19940.411$   
 $\phi_y = 0.83945231$   
 $A = -0.00249769$   
 $B = 0.03303234$   
with  $E_s = 200000.00$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

- Calculation of  $\phi_p$  -

From table 10-8:  $\phi_p = 0.0092006$

with:

- Columns not controlled by inadequate development or splicing along the clear height because  $I_b/I_d \geq 1$   
shear control ratio  $V_y E / V_{col} E = 1.14637$   
 $d = 407.00$   
 $s = 150.00$   
 $t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00283171$   
 $A_v = 78.53982$ , is the area of every stirrup  
 $L_{stir} = 1060.00$ , is the total Length of all stirrups parallel to loading (shear) direction  
The term  $2 * t_f / b_w * (f_{fe} / f_s)$  is implemented to account for FRP contribution  
where  $f = 2 * t_f / b_w$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength  
All these variables have already been given in Shear control ratio calculation.

NUD = 1.4055E+006  
Ag = 140000.00  
f<sub>cE</sub> = 18.00  
f<sub>yE</sub> = f<sub>yI</sub> = 444.44  
p<sub>l</sub> = Area\_Tot\_Long\_Rein/(b\*d) = 0.05063599  
b = 200.00  
d = 407.00  
f<sub>cE</sub> = 18.00

-----  
End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1  
At local axis: 3  
Integration Section: (b)  
-----