

# Detailed Member Calculations

**Units: N&mm**

**Regulation: ASCE 41-17**

## Calculation No. 1

column C1, Floor 1

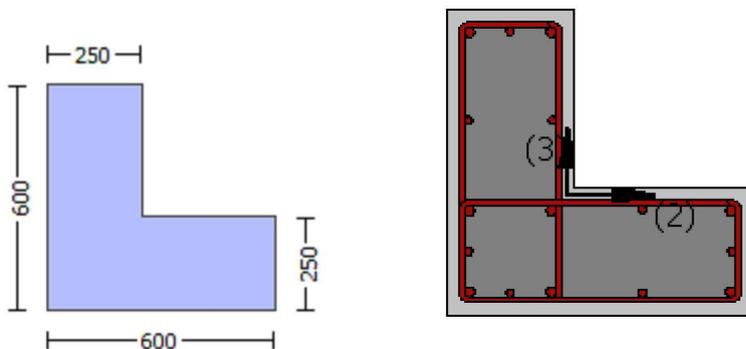
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: Start

Local Axis: (2)



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

At local axis: 2

Integration Section: (a)

Section Type: rclcs

Constant Properties

Knowledge Factor,  $\gamma = 0.86$

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

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

Consequently:

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

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

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

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

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Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with  $l_o/l_{o,min} = l_b/l_d = 0.30$

No FRP Wrapping

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Stepwise Properties

EDGE -A-

Bending Moment,  $M_a = -1.0386E+007$

Shear Force,  $V_a = -3387.623$

EDGE -B-

Bending Moment,  $M_b = 220916.627$

Shear Force,  $V_b = 3387.623$

BOTH EDGES

Axial Force,  $F = -9591.168$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $A_{sc} = 4121.77$

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,  $Db_{L,ten} = 17.71429$

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New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 431734.388$

$V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{CoI} = 431734.388$

$V_{CoI} = 431734.388$

$k_n = 1.00$

displacement\_ductility\_demand = 0.01083738

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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).

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

$f_c' = 25.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$M_u = 1.0386E+007$

$V_u = 3387.623$

$d = 0.8 \cdot h = 480.00$

$N_u = 9591.168$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 356047.167$

where:

$V_{s1} = 104719.755$  is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 500.00$   
 $s = 150.00$   
Vs1 is multiplied by Col1 = 1.00  
 $s/d = 0.75$   
Vs2 = 251327.412 is calculated for section flange, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 150.00$   
Vs2 is multiplied by Col2 = 1.00  
 $s/d = 0.3125$   
Vf ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440:  $V_s + V_f \leq 398582.298$   
 $bw = 250.00$

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

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

From analysis, chord rotation =  $6.8499106E-005$   
 $y = (M_y * L_s / 3) / E_{eff} = 0.00632063$  ((4.29), Biskinis Phd))  
 $M_y = 3.3303E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3066.001  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 5.3849E+013$   
 $factor = 0.30$   
 $A_g = 237500.00$   
 $f_c' = 33.00$   
 $N = 9591.168$   
 $E_c * I_g = 1.7950E+014$

Calculation of Yielding Moment  $M_y$

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

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 4.3407598E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 311.2112$   
 $d = 557.00$   
 $y = 0.35641753$   
 $A = 0.0298211$   
 $B = 0.01920334$   
with  $pt = 0.01254381$   
 $pc = 0.00595605$   
 $pv = 0.01109992$   
 $N = 9591.168$   
 $b = 250.00$   
 $\rho = 0.07719928$   
 $y_{comp} = 1.1116859E-005$   
with  $f_c = 33.00$   
 $E_c = 26999.444$   
 $y = 0.35529928$   
 $A = 0.02944325$   
 $B = 0.01898202$   
with  $E_s = 200000.00$

Calculation of ratio  $I_b / I_d$

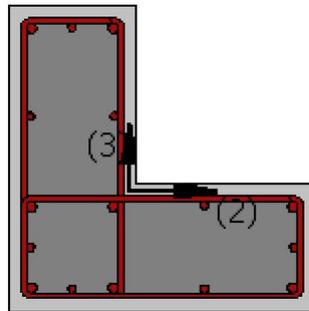
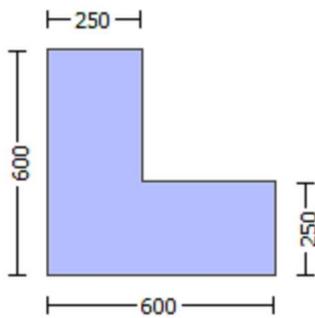
Inadequate Lap Length with  $I_b / I_d = 0.30$

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

At local axis: 2  
Integration Section: (a)

## Calculation No. 2

column C1, Floor 1  
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)  
Analysis: Uniform +X  
Check: Chord rotation capacity (  $\theta$  )  
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: rdcs

Constant Properties

Knowledge Factor,  $\gamma = 0.86$

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

Consequently:

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

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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

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

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Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length, L = 3000.00  
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_o/l_{o,min} = 0.30$   
No FRP Wrapping

#### Stepwise Properties

At local axis: 3  
EDGE -A-  
Shear Force,  $V_a = 0.33706551$   
EDGE -B-  
Shear Force,  $V_b = -0.33706551$   
BOTH EDGES  
Axial Force,  $F = -8883.863$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 4121.77$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten} = 1746.726$   
-Compression:  $A_{st,com} = 829.3805$   
-Middle:  $A_{st,mid} = 1545.664$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.71876853$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 358969.728$   
with  
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 5.3845E+008$   
 $Mu_{1+} = 5.3845E+008$ , 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  
 $Mu_{1-} = 2.9011E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 5.3845E+008$   
 $Mu_{2+} = 5.3845E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination  
 $Mu_{2-} = 2.9011E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

#### Calculation of $Mu_{1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\phi_u = 1.2895006E-005$   
 $M_u = 5.3845E+008$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00193327$$

$$N = 8883.863$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00616264$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.00616264$$

$$\phi_w \text{ (5.4c)} = 0.00443103$$

$$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

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)

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 $p_{sh,x}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $p_{sh,y}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $s = 150.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

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

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

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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

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

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

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

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

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

with  $fs_1 = fs = 389.0139$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

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

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

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

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

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

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

with  $fs_2 = fs = 389.0139$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$su_v = 0.00512$

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

$l_0/l_{0u,min} = l_b/l_d = 0.30$

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

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

considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY

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

$\gamma_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $f_{sv} = f_s = 389.0139$

with  $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.14787021$

$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.07021175$

$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.13084918$

and confined core properties:

$b = 190.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 33.00$

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

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

$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.20564193$

$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.09764293$

$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.18197092$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

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

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$s_u (4.8) = 0.28715809$

$M_u = M_{Rc} (4.15) = 5.3845E+008$

$u = s_u (4.1) = 1.2895006E-005$

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Calculation of ratio  $l_b/l_d$

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Inadequate Lap Length with  $l_b/l_d = 0.30$   
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Calculation of  $M_{u1}$ -  
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Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.0873764E-005$

$M_u = 2.9011E+008$   
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with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00080553$

$N = 8883.863$

$f_c = 33.00$

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

Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, cc) = 0.00616264$

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

From (5.4b), TBDY:  $c_u = 0.00616264$

$w_e (5.4c) = 0.00443103$

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$

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

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

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$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

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)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

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

$c$  = confinement factor = 1.00

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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

$l_0/l_{ou,min} = l_b/l_d = 0.30$

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

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, ASCE41-17.

with  $fs_1 = fs = 389.0139$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

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

$l_0/l_{ou,min} = l_b/l_{b,min} = 0.30$

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

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, ASCE41-17.

with  $fs_2 = fs = 389.0139$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$su_v = 0.00512$

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

$$l_0/l_{ou,min} = l_b/l_d = 0.30$$

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

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

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY

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

$\gamma_1$ ,  $sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } f_{sv} = f_s = 389.0139$$

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.0292549$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.06161259$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.05452049$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.00$$

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

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.03435585$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.07235549$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.0640268$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.15465327$$

$$M_u = M_{Rc} (4.14) = 2.9011E+008$$

$$u = s_u (4.1) = 1.0873764E-005$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $M_{u2+}$

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

$$u = 1.2895006E-005$$

$$M_u = 5.3845E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00193327$$

$$N = 8883.863$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, cc) = 0.00616264$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.00616264$$

$$\omega_e (5.4c) = 0.00443103$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

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)

-----  
 $p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $s = 150.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

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

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

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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

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

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

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, ASCE41-17.

with  $fs_1 = fs = 389.0139$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

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

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

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

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, ASCE41-17.

with  $fs_2 = fs = 389.0139$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$su_v = 0.00512$

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

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

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

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

considering characteristic value  $fsy_v = fs_v/1.2$ , from table 5.1, TBDY

For calculation of  $esu_{v,nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered

characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

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

with  $f_{sv} = f_s = 389.0139$

with  $E_{sv} = E_s = 200000.00$

1 =  $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.14787021$

2 =  $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.07021175$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.13084918$

and confined core properties:

$b = 190.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 33.00$

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

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

1 =  $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.20564193$

2 =  $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09764293$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.18197092$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

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

--->

$su (4.8) = 0.28715809$

$Mu = MRc (4.15) = 5.3845E+008$

$u = su (4.1) = 1.2895006E-005$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $Mu_2$

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

$u = 1.0873764E-005$

$Mu = 2.9011E+008$

with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00080553$

$N = 8883.863$

$f_c = 33.00$

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

Final value of  $cu$ :  $cu^* = \text{shear\_factor} \cdot \text{Max}(cu, cc) = 0.00616264$

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

From (5.4b), TBDY:  $cu = 0.00616264$

$w_e (5.4c) = 0.00443103$

$ase = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) \cdot (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00321875$$

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)

$$psh,x \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00321875$$

$$Lstir \text{ (Length of stirrups along Y)} = 1460.00$$

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

$$Asec \text{ (section area)} = 237500.00$$

$$psh,y \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00321875$$

$$Lstir \text{ (Length of stirrups along X)} = 1460.00$$

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

$$Asec \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$fywe = 694.45$$

$$fce = 33.00$$

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

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

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

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

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

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

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

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

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

$$\text{with } fs1 = fs = 389.0139$$

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

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

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

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

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

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

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

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

$$\text{with } fs2 = fs = 389.0139$$

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

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

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

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

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

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

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

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

$$\text{with } fsv = fs = 389.0139$$

with  $E_{sv} = E_s = 200000.00$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.0292549$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.06161259$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.05452049$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.00$$

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

$c$  = confinement factor = 1.00

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03435585$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07235549$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0640268$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.15465327$$

$$M_u = M_{Rc} (4.14) = 2.9011E+008$$

$$u = s_u (4.1) = 1.0873764E-005$$

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

-----  
Inadequate Lap Length with  $l_b/d = 0.30$   
-----  
-----  
-----

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 499423.271$   
-----

Calculation of Shear Strength at edge 1,  $V_{r1} = 515023.161$

$$V_{r1} = V_{CoI} ((10.3), ASCE 41-17) = k_{nl} * V_{CoI0}$$

$$V_{CoI0} = 515023.161$$

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

-----  
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 (normal-weight concrete)

$$f_c' = 33.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.9058$$

$$M_u = 470.1336$$

$$V_u = 0.33706551$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.863$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 395611.129$$

where:

$V_{s1} = 279254.914$  is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 150.00$$

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

$$s/d = 0.3125$$

$V_{s2} = 116356.214$  is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 150.00$$

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

$$s/d = 0.75$$

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 457936.196$$

bw = 250.00

Calculation of Shear Strength at edge 2, Vr2 = 499423.271  
Vr2 = VCol ((10.3), ASCE 41-17) = knl\*VCol0  
VCol0 = 499423.271  
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' = 33.00, but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
M/Vd = 3.34246  
Mu = 540.7808  
Vu = 0.33706551  
d = 0.8\*h = 480.00  
Nu = 8883.863  
Ag = 150000.00  
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 395611.129  
where:  
Vs1 = 279254.914 is calculated for section web, with:  
d = 480.00  
Av = 157079.633  
fy = 555.56  
s = 150.00  
Vs1 is multiplied by Col1 = 1.00  
s/d = 0.3125  
Vs2 = 116356.214 is calculated for section flange, with:  
d = 200.00  
Av = 157079.633  
fy = 555.56  
s = 150.00  
Vs2 is multiplied by Col2 = 1.00  
s/d = 0.75  
Vf ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440: Vs + Vf <= 457936.196  
bw = 250.00

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, = 0.86  
Mean strength values are used for both shear and moment calculations.  
Consequently:  
New material of Primary Member: Concrete Strength, fc = fcm = 33.00  
New material of Primary Member: Steel Strength, fs = fsm = 555.56  
Concrete Elasticity, Ec = 26999.444  
Steel Elasticity, Es = 200000.00  
#####  
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  
New material: Steel Strength, fs = 1.25\*fsm = 694.45  
#####  
Max Height, Hmax = 600.00  
Min Height, Hmin = 250.00

Max Width,  $W_{max} = 600.00$   
Min Width,  $W_{min} = 250.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.00  
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_o/l_{o,min} = 0.30$   
No FRP Wrapping

-----  
Stepwise Properties  
-----

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = 0.33706551$   
EDGE -B-  
Shear Force,  $V_b = -0.33706551$   
BOTH EDGES  
Axial Force,  $F = -8883.863$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 4121.77$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten} = 1746.726$   
-Compression:  $A_{st,com} = 829.3805$   
-Middle:  $A_{st,mid} = 1545.664$

-----  
-----  
Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.71876765$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 358969.728$   
with  
 $M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 5.3845E+008$   
 $M_{u1+} = 5.3845E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction  
which is defined for the static loading combination  
 $M_{u1-} = 2.9011E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment  
direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 5.3845E+008$   
 $M_{u2+} = 5.3845E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction  
which is defined for the the static loading combination  
 $M_{u2-} = 2.9011E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment  
direction which is defined for the the static loading combination

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

-----  
Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\phi_u = 1.2895006E-005$   
 $M_u = 5.3845E+008$

-----  
with full section properties:

$b = 250.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00193327$   
 $N = 8883.863$   
 $f_c = 33.00$   
 $\phi_o$  (5A.5, TBDY) = 0.002  
Final value of  $\phi_{cu}$ :  $\phi_{cu}^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.00616264$

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

From (5.4b), TBDY:  $c_u = 0.00616264$

$w_e$  (5.4c) = 0.00443103

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

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) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

$p_{sh,y}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

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

$c$  = confinement factor = 1.00

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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

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

$su_1 = 0.4 * e_{su1\_nominal}$  ((5.5), TBDY) = 0.032

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

For calculation of  $e_{su1\_nominal}$  and  $y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , it is considered characteristic value  $f_{sy1} = f_s/1.2$ , from table 5.1, TBDY.

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

with  $f_{s1} = f_s = 389.0139$

with  $E_{s1} = E_s = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

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

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

$su_2 = 0.4 * e_{su2\_nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $e_{su2\_nominal} = 0.08$ ,

For calculation of  $e_{su2\_nominal}$  and  $y_2$ ,  $sh_2$ ,  $ft_2$ ,  $fy_2$ , it is considered characteristic value  $f_{sy2} = f_s/1.2$ , from table 5.1, TBDY.

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

with  $f_{s2} = f_s = 389.0139$

with  $E_{s2} = E_s = 200000.00$

$y_v = 0.00140044$

$shv = 0.0044814$   
 $ftv = 466.8167$   
 $fyv = 389.0139$   
 $suv = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou,min = lb/ld = 0.30$   
 $suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv$ ,  $shv,ftv,fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1,ft1,fy1$ , are also multiplied by  $Min(1,1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fsv = fs = 389.0139$   
 with  $Esv = Es = 200000.00$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.14787021$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.07021175$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.13084918$   
 and confined core properties:  
 $b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 33.00$   
 $cc (5A.5, TBDY) = 0.002$   
 $c = confinement\ factor = 1.00$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.20564193$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.09764293$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.18197092$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < vs,y2$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < vs,c$  - RHS eq.(4.5) is satisfied  
 --->  
 $su (4.8) = 0.28715809$   
 $Mu = MRc (4.15) = 5.3845E+008$   
 $u = su (4.1) = 1.2895006E-005$

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

-----  
 Inadequate Lap Length with  $lb/ld = 0.30$   
 -----  
 -----

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

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

$u = 1.0873764E-005$   
 $Mu = 2.9011E+008$

-----  
 with full section properties:

$b = 600.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00080553$   
 $N = 8883.863$   
 $fc = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = shear\_factor * Max( cu, cc) = 0.00616264$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.00616264$   
 $we (5.4c) = 0.00443103$

$$ase = \text{Max}(((Aconf,max - AnoConf) / Aconf,max) * (Aconf,min / Aconf,max), 0) = 0.21805635$$

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 = 169100.00 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 = 98400.00 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 = 105733.333 is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00321875$$

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)

$$psh,x \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00321875$$

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

$$psh,y \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00321875$$

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

$$s = 150.00$$

$$fywe = 694.45$$

$$fce = 33.00$$

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

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

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

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

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

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

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

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

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

with  $fs1 = fs = 389.0139$

with  $Es1 = Es = 200000.00$

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

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

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

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

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

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

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

with  $fs2 = fs = 389.0139$

with  $Es2 = Es = 200000.00$

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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

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

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

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

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

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0292549

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.06161259

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.05452049

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 33.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.03435585

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.07235549

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.0640268

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.15465327

Mu = MRc (4.14) = 2.9011E+008

u = su (4.1) = 1.0873764E-005

-----  
Calculation of ratio lb/d

-----  
Inadequate Lap Length with lb/d = 0.30  
-----  
-----

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

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

u = 1.2895006E-005

Mu = 5.3845E+008  
-----

with full section properties:

b = 250.00

d = 557.00

d' = 43.00

v = 0.00193327

N = 8883.863

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.00616264

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

From (5.4b), TBDY: cu = 0.00616264

we (5.4c) = 0.00443103

ase = Max(((Aconf,max-AnoConf)/Aconf,max)\*(Aconf,min/Aconf,max),0) = 0.21805635

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00321875$

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) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $psh_y$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $s = 150.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

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

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

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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

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

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

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

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

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

with  $fs_1 = fs = 389.0139$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

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

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

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

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

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

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

with  $fs_2 = fs = 389.0139$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$su_v = 0.00512$

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

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

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

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

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

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

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

$$\text{with } fsv = fs = 389.0139$$

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.14787021$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.07021175$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.13084918$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 33.00$$

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

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.20564193$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.09764293$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.18197092$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs,y2$  - LHS eq.(4.5) is not satisfied

--->

$v < vs,c$  - RHS eq.(4.5) is satisfied

--->

$$su (4.8) = 0.28715809$$

$$Mu = MRc (4.15) = 5.3845E+008$$

$$u = su (4.1) = 1.2895006E-005$$

Calculation of ratio  $lb/ld$

Inadequate Lap Length with  $lb/ld = 0.30$

Calculation of  $Mu2$ -

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

$$u = 1.0873764E-005$$

$$Mu = 2.9011E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00080553$$

$$N = 8883.863$$

$$fc = 33.00$$

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

$$\text{Final value of } cu: cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00616264$$

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

$$\text{From (5.4b), TBDY: } cu = 0.00616264$$

$$we (5.4c) = 0.00443103$$

$$ase = \text{Max}(((Aconf,max - AnoConf)/Aconf,max) * (Aconf,min/Aconf,max), 0) = 0.21805635$$

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.

$Aconf,max = 169100.00$  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 = 98400.00 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 = 105733.333 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) = 0.00321875

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) = 0.00321875

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 150.00

fywe = 694.45

fce = 33.00

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

c = confinement factor = 1.00

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

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

lo/lou,min = lb/d = 0.30

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

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

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

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

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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

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

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

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

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

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

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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

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

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

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

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

with  $f_{sv} = f_s = 389.0139$

with  $E_{sv} = E_s = 200000.00$

1 =  $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0292549$

2 =  $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.06161259$

$v = Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.05452049$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

$f_{cc}$  (5A.2, TBDY) = 33.00

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

$c$  = confinement factor = 1.00

1 =  $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03435585$

2 =  $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.07235549$

$v = Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.0640268$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su$  (4.9) = 0.15465327

$\mu = MR_c$  (4.14) = 2.9011E+008

$u = su$  (4.1) = 1.0873764E-005

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

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
-----  
-----  
-----

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 499423.877$   
-----

Calculation of Shear Strength at edge 1,  $V_{r1} = 515022.351$

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

$V_{Col0} = 515022.351$

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

-----  
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)

$f_c' = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.90582$

$\mu = 470.1368$

$V_u = 0.33706551$

$d = 0.8 \cdot h = 480.00$

$N_u = 8883.863$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$

where:

$V_{s1} = 116356.214$  is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 150.00$

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

$s/d = 0.75$

$V_{s2} = 279254.914$  is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 150.00$

Vs2 is multiplied by Col2 = 1.00  
s/d = 0.3125  
Vf ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440: Vs + Vf <= 457936.196  
bw = 250.00

-----  
Calculation of Shear Strength at edge 2, Vr2 = 499423.877  
Vr2 = VCol ((10.3), ASCE 41-17) = knl\*VCol0  
VCol0 = 499423.877  
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' = 33.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)  
M/Vd = 3.34244  
Mu = 540.7776  
Vu = 0.33706551  
d = 0.8\*h = 480.00  
Nu = 8883.863  
Ag = 150000.00  
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 395611.129

where:

Vs1 = 116356.214 is calculated for section web, with:

d = 200.00  
Av = 157079.633  
fy = 555.56  
s = 150.00

Vs1 is multiplied by Col1 = 1.00  
s/d = 0.75

Vs2 = 279254.914 is calculated for section flange, with:

d = 480.00  
Av = 157079.633  
fy = 555.56  
s = 150.00

Vs2 is multiplied by Col2 = 1.00  
s/d = 0.3125  
Vf ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440: Vs + Vf <= 457936.196  
bw = 250.00

-----  
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, = 0.86  
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.  
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
New material of Primary Member: Concrete Strength, fc = fcm = 33.00  
New material of Primary Member: Steel Strength, fs = fsm = 555.56  
Concrete Elasticity, Ec = 26999.444  
Steel Elasticity, Es = 200000.00  
Max Height, Hmax = 600.00  
Min Height, Hmin = 250.00

Max Width,  $W_{max}$  = 600.00  
Min Width,  $W_{min}$  = 250.00  
Cover Thickness,  $c$  = 25.00  
Element Length,  $L$  = 3000.00  
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
No FRP Wrapping

-----  
Stepwise Properties  
-----

Bending Moment,  $M$  = -473533.503  
Shear Force,  $V_2$  = -3387.623  
Shear Force,  $V_3$  = 217.5031  
Axial Force,  $F$  = -9591.168  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st}$  = 0.00  
-Compression:  $A_{sc}$  = 4121.77  
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,  $DbL$  = 17.71429

-----  
-----  
New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0^*$   $u = 0.00448821$   
 $u = y + p = 0.00448821$

-----  
- Calculation of  $y$  -  
-----

$y = (M_y * L_s / 3) / E_{eff} = 0.00448821$  ((4.29), Biskinis Phd)  
 $M_y = 3.3303E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 2177.135  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 5.3849E+013$   
 $factor = 0.30$   
 $A_g = 237500.00$   
 $f_c' = 33.00$   
 $N = 9591.168$   
 $E_c * I_g = 1.7950E+014$

-----  
-----  
Calculation of Yielding Moment  $M_y$   
-----

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

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 4.3407598E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b/l_d)^{2/3}) = 311.2112$   
 $d = 557.00$   
 $y = 0.35641753$   
 $A = 0.0298211$   
 $B = 0.01920334$   
with  $pt = 0.01254381$   
 $pc = 0.00595605$   
 $pv = 0.01109992$   
 $N = 9591.168$   
 $b = 250.00$   
 $" = 0.07719928$   
 $y_{comp} = 1.1116859E-005$

with  $f_c = 33.00$   
 $E_c = 26999.444$   
 $y = 0.35529928$   
 $A = 0.02944325$   
 $B = 0.01898202$   
with  $E_s = 200000.00$

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

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$

-----  
- Calculation of  $\rho$  -

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

with:

- Columns not controlled by inadequate development or splicing along the clear height because  $l_b/l_d \geq 1$   
shear control ratio  $V_y E / V_{CoI} E = 0.71876853$

$d = 557.00$

$s = 0.00$

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

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

$L_{stir} = 1460.00$ , 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.

$NUD = 9591.168$

$A_g = 237500.00$

$f_{cE} = 33.00$

$f_{yE} = f_{yI} = 0.00$

$\rho_l = \text{Area\_Tot\_Long\_Rein} / (b * d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_{cE} = 33.00$

-----  
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

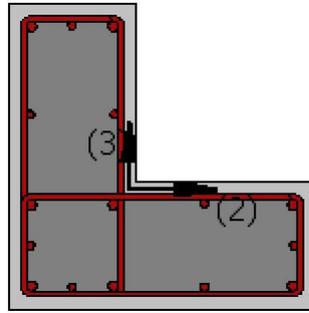
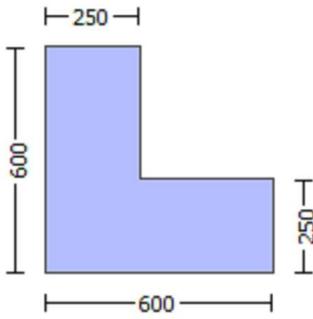
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: Start

Local Axis: (3)



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

At local axis: 3

Integration Section: (a)

Section Type: rdcs

Constant Properties

Knowledge Factor,  $\gamma = 0.86$

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

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

Consequently:

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

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

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

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

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with  $l_o/l_{o,min} = l_b/d = 0.30$

No FRP Wrapping

Stepwise Properties

EDGE -A-

Bending Moment,  $M_a = -473533.503$

Shear Force,  $V_a = 217.5031$

EDGE -B-

Bending Moment,  $M_b = -178244.622$

Shear Force,  $V_b = -217.5031$

BOTH EDGES

Axial Force,  $F = -9591.168$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $A_{sc} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{st,ten} = 1746.726$

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

-Middle:  $A_{sl,mid} = 1545.664$

Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 17.71429$

New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 431734.388$

$V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{CoIO} = 431734.388$

$V_{CoI} = 431734.388$

$k_n = 1.00$

$displacement\_ductility\_demand = 0.00416928$

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)

$f_c' = 25.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 473533.503$

$V_u = 217.5031$

$d = 0.8 \cdot h = 480.00$

$N_u = 9591.168$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 356047.167$

where:

$V_{s1} = 251327.412$  is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 150.00$

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

$s/d = 0.3125$

$V_{s2} = 104719.755$  is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 150.00$

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

$s/d = 0.75$

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

From (11-11), ACI 440:  $V_s + V_f \leq 398582.298$

$b_w = 250.00$

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

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

From analysis, chord rotation  $\theta = 1.8712628E-005$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00448821$  ((4.29), Biskinis Phd)

$M_y = 3.3303E+008$

$L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 2177.135

From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 5.3849E+013$

$factor = 0.30$

$A_g = 237500.00$

$f_c' = 33.00$

$N = 9591.168$

$E_c \cdot I_g = 1.7950E+014$

Calculation of Yielding Moment  $M_y$

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

y = Min( y\_ten, y\_com)  
y\_ten = 4.3407598E-006  
with ((10.1), ASCE 41-17) fy = Min(fy, 1.25\*fy\*(lb/d)^ 2/3) = 311.2112  
d = 557.00  
y = 0.35641753  
A = 0.0298211  
B = 0.01920334  
with pt = 0.01254381  
pc = 0.00595605  
pv = 0.01109992  
N = 9591.168  
b = 250.00  
" = 0.07719928  
y\_comp = 1.1116859E-005  
with fc = 33.00  
Ec = 26999.444  
y = 0.35529928  
A = 0.02944325  
B = 0.01898202  
with Es = 200000.00

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

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

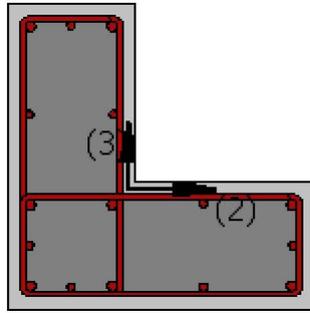
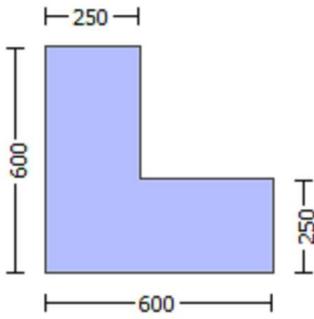
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( u)

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,  $\gamma = 0.86$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$

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

#####  
 Max Height,  $H_{max} = 600.00$   
 Min Height,  $H_{min} = 250.00$   
 Max Width,  $W_{max} = 600.00$   
 Min Width,  $W_{min} = 250.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.00  
 Element Length,  $L = 3000.00$   
 Primary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Inadequate Lap Length with  $l_o/l_{ou,min} = 0.30$   
 No FRP Wrapping

Stepwise Properties

At local axis: 3  
 EDGE -A-  
 Shear Force,  $V_a = 0.33706551$   
 EDGE -B-  
 Shear Force,  $V_b = -0.33706551$   
 BOTH EDGES  
 Axial Force,  $F = -8883.863$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $A_{sl,t} = 0.00$   
 -Compression:  $A_{sl,c} = 4121.77$   
 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 ,  $V_e/V_r = 0.71876853$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 358969.728$

with  
 $M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 5.3845E+008$   
 $M_{u1+} = 5.3845E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination  
 $M_{u1-} = 2.9011E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 5.3845E+008$   
 $M_{u2+} = 5.3845E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination  
 $M_{u2-} = 2.9011E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of  $M_{u1+}$

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

$\phi_u = 1.2895006E-005$

$M_u = 5.3845E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00193327$

$N = 8883.863$

$f_c = 33.00$

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

Final value of  $\phi_{cu}$ :  $\phi_{cu}^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.00616264$

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

From (5.4b), TBDY:  $\phi_{cu} = 0.00616264$

$\phi_{we} (5.4c) = 0.00443103$

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\phi_{psh,min} = \text{Min}(\phi_{psh,x}, \phi_{psh,y}) = 0.00321875$

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)

$\phi_{psh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

$\phi_{psh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 694.45$

fce = 33.00

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

c = confinement factor = 1.00

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

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

lo/lou,min = lb/d = 0.30

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

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

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

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

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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

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

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

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

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

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

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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

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

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

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

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

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.14787021

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.07021175

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.13084918

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 33.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.20564193

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.09764293

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.18197092

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->  
v < vs,y2 - LHS eq.(4.5) is not satisfied  
--->  
v < vs,c - RHS eq.(4.5) is satisfied  
--->  
su (4.8) = 0.28715809  
Mu = MRc (4.15) = 5.3845E+008  
u = su (4.1) = 1.2895006E-005

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

Inadequate Lap Length with lb/ld = 0.30  
-----  
-----  
-----

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

-----  
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:  
u = 1.0873764E-005  
Mu = 2.9011E+008  
-----

with full section properties:

b = 600.00  
d = 557.00  
d' = 43.00  
v = 0.00080553  
N = 8883.863  
fc = 33.00  
co (5A.5, TBDY) = 0.002  
Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.00616264  
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY: cu = 0.00616264  
we (5.4c) = 0.00443103  
ase = Max(((Aconf,max-AnoConf)/Aconf,max)\*(Aconf,min/Aconf,max),0) = 0.21805635  
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 = 169100.00 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 = 98400.00 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 = 105733.333 is the unconfined core area which is equal to bi2/6 as defined at (A.2).  
psh,min = Min(psh,x , psh,y) = 0.00321875  
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) = 0.00321875  
Lstir (Length of stirrups along Y) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00  
-----

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875  
Lstir (Length of stirrups along X) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00  
-----

s = 150.00  
fywe = 694.45  
fce = 33.00  
From ((5.A5), TBDY), TBDY: cc = 0.002  
c = confinement factor = 1.00

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

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

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

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

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

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

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

$$\text{with } fs1 = fs = 389.0139$$

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

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

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

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

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

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

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

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

$$\text{with } fs2 = fs = 389.0139$$

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

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

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

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

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

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

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

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

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

$$\text{with } fsv = fs = 389.0139$$

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.0292549$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.06161259$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.05452049$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 33.00$$

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

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.03435585$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.07235549$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.0640268$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.15465327  
Mu = MRc (4.14) = 2.9011E+008  
u = su (4.1) = 1.0873764E-005

-----  
Calculation of ratio lb/ld

-----  
Inadequate Lap Length with lb/ld = 0.30  
-----

-----  
Calculation of Mu2+

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

u = 1.2895006E-005  
Mu = 5.3845E+008

-----  
with full section properties:

b = 250.00  
d = 557.00  
d' = 43.00  
v = 0.00193327  
N = 8883.863  
fc = 33.00  
co (5A.5, TBDY) = 0.002  
Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.00616264  
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY: cu = 0.00616264  
we (5.4c) = 0.00443103

ase = Max(((Aconf,max-AnoConf)/Aconf,max)\*(Aconf,min/Aconf,max),0) = 0.21805635

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 = 169100.00 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 = 98400.00 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 = 105733.333 is the unconfined core area which is equal to bi<sup>2</sup>/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00321875

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) = 0.00321875

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

-----  
psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

-----  
s = 150.00

fywe = 694.45

fce = 33.00

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

c = confinement factor = 1.00

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

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

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

$$s_u1 = 0.4 * e_{su1,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{su1,nominal} = 0.08$ ,

For calculation of  $e_{su1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
characteristic value  $f_{sy1} = f_{s1}/1.2$ , from table 5.1, TBDY.

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

$$\text{with } f_{s1} = f_s = 389.0139$$

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

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$s_u2 = 0.00512$$

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

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

$$s_u2 = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{su2,nominal} = 0.08$ ,

For calculation of  $e_{su2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.

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

$$\text{with } f_{s2} = f_s = 389.0139$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$s_{uv} = 0.00512$$

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

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

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

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

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

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

$$\text{with } f_{sv} = f_s = 389.0139$$

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

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.14787021$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.07021175$$

$$v = A_{s1,mid}/(b*d) * (f_{sv}/f_c) = 0.13084918$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.00$$

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

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

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.20564193$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.09764293$$

$$v = A_{s1,mid}/(b*d) * (f_{sv}/f_c) = 0.18197092$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

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

--->

$$s_u (4.8) = 0.28715809$$

$$M_u = M_{Rc} (4.15) = 5.3845E+008$$

$$u = s_u (4.1) = 1.2895006E-005$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_2$

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

$$\mu_u = 1.0873764E-005$$

$$\mu = 2.9011E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00080553$$

$$N = 8883.863$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, c_c) = 0.00616264$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.00616264$$

$$\mu_{ue} \text{ (5.4c)} = 0.00443103$$

$$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.00321875$$

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)

$$\mu_{psh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

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

$$A_{sec} \text{ (section area)} = 237500.00$$

$$\mu_{psh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

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

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

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

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

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

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

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

$$s_u1 = 0.4 * e_{s1\_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{s1\_nominal} = 0.08$ ,

For calculation of  $e_{s1\_nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $f_{sy1} = f_{s1}/1.2$ , from table 5.1, TBDY.

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

$$\text{with } f_{s1} = f_s = 389.0139$$

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

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$s_u2 = 0.00512$$

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

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

$$s_u2 = 0.4 * e_{s2\_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{s2\_nominal} = 0.08$ ,

For calculation of  $e_{s2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.

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

$$\text{with } f_{s2} = f_s = 389.0139$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$s_{u,v} = 0.00512$$

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

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

$$s_{u,v} = 0.4 * e_{s_{u,v}\_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{s_{u,v}\_nominal} = 0.08$ ,

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

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

$$\text{with } f_{s_{v}} = f_s = 389.0139$$

$$\text{with } E_{s_{v}} = E_s = 200000.00$$

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.0292549$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.06161259$$

$$v = A_{s1,mid}/(b*d) * (f_{s_{v}}/f_c) = 0.05452049$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.00$$

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

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

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.03435585$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.07235549$$

$$v = A_{s1,mid}/(b*d) * (f_{s_{v}}/f_c) = 0.0640268$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---

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

---

$$s_u (4.9) = 0.15465327$$

$$\mu = M_{Rc} (4.14) = 2.9011E+008$$

$$u = s_u (4.1) = 1.0873764E-005$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

-----  
-----  
-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 499423.271$   
-----

Calculation of Shear Strength at edge 1,  $V_{r1} = 515023.161$   
 $V_{r1} = V_{Co1} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{Co10}$   
 $V_{Co10} = 515023.161$   
 $k_{nl} = 1$  (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)  
 $f'_c = 33.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.9058$   
 $\mu_u = 470.1336$   
 $V_u = 0.33706551$   
 $d = 0.8 * h = 480.00$   
 $N_u = 8883.863$   
 $A_g = 150000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$   
where:  
 $V_{s1} = 279254.914$  is calculated for section web, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.3125$   
 $V_{s2} = 116356.214$  is calculated for section flange, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.75$   
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 0.00$   
From (11-11), ACI 440:  $V_s + V_f \leq 457936.196$   
 $b_w = 250.00$   
-----

-----  
Calculation of Shear Strength at edge 2,  $V_{r2} = 499423.271$   
 $V_{r2} = V_{Co2} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{Co10}$   
 $V_{Co10} = 499423.271$   
 $k_{nl} = 1$  (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)  
 $f'_c = 33.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 3.34246$   
 $\mu_u = 540.7808$   
 $V_u = 0.33706551$   
 $d = 0.8 * h = 480.00$   
 $N_u = 8883.863$   
 $A_g = 150000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$   
where:  
 $V_{s1} = 279254.914$  is calculated for section web, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$

s/d = 0.3125

Vs2 = 116356.214 is calculated for section flange, with:

d = 200.00

Av = 157079.633

fy = 555.56

s = 150.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.75

Vf ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: Vs + Vf <= 457936.196

bw = 250.00

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, = 0.86

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

Consequently:

New material of Primary Member: Concrete Strength, fc = fcm = 33.00

New material of Primary Member: Steel Strength, fs = fsm = 555.56

Concrete Elasticity, Ec = 26999.444

Steel Elasticity, Es = 200000.00

#####

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

New material: Steel Strength, fs = 1.25\*fsm = 694.45

#####

Max Height, Hmax = 600.00

Min Height, Hmin = 250.00

Max Width, Wmax = 600.00

Min Width, Wmin = 250.00

Cover Thickness, c = 25.00

Mean Confinement Factor overall section = 1.00

Element Length, L = 3000.00

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with lo/lo,min = 0.30

No FRP Wrapping

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, Va = 0.33706551

EDGE -B-

Shear Force, Vb = -0.33706551

BOTH EDGES

Axial Force, F = -8883.863

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: Aslt = 0.00

-Compression: Aslc = 4121.77

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $Asl,ten = 1746.726$   
-Compression:  $Asl,com = 829.3805$   
-Middle:  $Asl,mid = 1545.664$

Calculation of Shear Capacity ratio ,  $Ve/Vr = 0.71876765$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $Ve = (Mpr1 + Mpr2)/ln = 358969.728$

with  
 $Mpr1 = \text{Max}(\mu_{1+}, \mu_{1-}) = 5.3845E+008$   
 $\mu_{1+} = 5.3845E+008$ , 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  
 $\mu_{1-} = 2.9011E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $Mpr2 = \text{Max}(\mu_{2+}, \mu_{2-}) = 5.3845E+008$   
 $\mu_{2+} = 5.3845E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination  
 $\mu_{2-} = 2.9011E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of  $\mu_{1+}$

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

$\mu = 1.2895006E-005$   
 $\mu_u = 5.3845E+008$

with full section properties:

$b = 250.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00193327$   
 $N = 8883.863$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
Final value of  $\mu_c$ :  $\mu_c^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.00616264$   
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY:  $\mu_c = 0.00616264$   
we (5.4c) = 0.00443103

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh,min = \text{Min}(psh_x, psh_y) = 0.00321875$

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)

$psh_x ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

$psh_y ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

Asec (section area) = 237500.00

s = 150.00

fywe = 694.45

fce = 33.00

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

c = confinement factor = 1.00

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

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

lo/lou,min = lb/ld = 0.30

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

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

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

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

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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

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

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

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

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

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

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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

lo/lou,min = lb/ld = 0.30

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

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

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

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

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.14787021

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.07021175

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.13084918

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 33.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.20564193

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.09764293$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.18197092$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

----

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

----

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

----

$$s_u(4.8) = 0.28715809$$

$$M_u = M_{Rc}(4.15) = 5.3845E+008$$

$$u = s_u(4.1) = 1.2895006E-005$$

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

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$

-----  
Calculation of  $M_{u1}$ -

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

$$u = 1.0873764E-005$$

$$M_u = 2.9011E+008$$

-----  
with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00080553$$

$$N = 8883.863$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.00616264$$

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

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.00616264$$

$$\phi_{cc}(5.4c) = 0.00443103$$

$$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\phi_{psh,min} = \text{Min}(\phi_{psh,x}, \phi_{psh,y}) = 0.00321875$$

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)

$$\phi_{psh,x}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

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

$$A_{sec} \text{ (section area)} = 237500.00$$

$$\phi_{psh,y}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

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

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$fywe = 694.45$$

$$fce = 33.00$$

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

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

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

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

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

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

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

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

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

$$\text{with } fs1 = fs = 389.0139$$

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

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

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

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

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

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

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

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

$$\text{with } fs2 = fs = 389.0139$$

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

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

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

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

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

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

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

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

$$\text{with } fsv = fs = 389.0139$$

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0292549$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.06161259$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.05452049$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 33.00$$

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

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.03435585$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.07235549$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.0640268$$

Case/Assumption: Unconfinedsd full section - Steel rupture

satisfies Eq. (4.3)

--->

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

--->

$\mu_u$  (4.9) = 0.15465327

$\mu_u = M_{Rc}$  (4.14) = 2.9011E+008

$u = \mu_u$  (4.1) = 1.0873764E-005

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{u2+}$

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

$\mu_u = 1.2895006E-005$

$\mu_u = 5.3845E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00193327$

$N = 8883.863$

$f_c = 33.00$

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

Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \mu_c) = 0.00616264$

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

From (5.4b), TBDY:  $\mu_u = 0.00616264$

$\mu_{ue}$  (5.4c) = 0.00443103

$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b^2/6$  as defined at (A.2).

$\mu_{sh,min} = \text{Min}(\mu_{sh,x}, \mu_{sh,y}) = 0.00321875$

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

$\mu_{sh,x}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

$\mu_{sh,y}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

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

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

$\mu_{y1} = 0.00140044$

$sh1 = 0.0044814$   
 $ft1 = 466.8167$   
 $fy1 = 389.0139$   
 $su1 = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/l_d = 0.30$   
 $su1 = 0.4 * esu1\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
 For calculation of  $esu1\_nominal$  and  $y1$ ,  $sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1$ ,  $sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 * (lb/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs1 = fs = 389.0139$   
 with  $Es1 = Es = 200000.00$   
 $y2 = 0.00140044$   
 $sh2 = 0.0044814$   
 $ft2 = 466.8167$   
 $fy2 = 389.0139$   
 $su2 = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/l_b,min = 0.30$   
 $su2 = 0.4 * esu2\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
 For calculation of  $esu2\_nominal$  and  $y2$ ,  $sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1$ ,  $sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 * (lb/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs2 = fs = 389.0139$   
 with  $Es2 = Es = 200000.00$   
 $yv = 0.00140044$   
 $shv = 0.0044814$   
 $ftv = 466.8167$   
 $fyv = 389.0139$   
 $suv = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/l_d = 0.30$   
 $suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv$ ,  $shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1$ ,  $sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 * (lb/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fsv = fs = 389.0139$   
 with  $Esv = Es = 200000.00$   
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.14787021$   
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.07021175$   
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.13084918$   
 and confined core properties:  
 $b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 33.00$   
 $cc (5A.5, TBDY) = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.20564193$   
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.09764293$   
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.18197092$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied

--->

$$su(4.8) = 0.28715809$$

$$Mu = MRc(4.15) = 5.3845E+008$$

$$u = su(4.1) = 1.2895006E-005$$

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

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

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

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

$$u = 1.0873764E-005$$

$$Mu = 2.9011E+008$$

-----  
with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00080553$$

$$N = 8883.863$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00616264$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.00616264$$

$$\phi_{ue}(5.4c) = 0.00443103$$

$$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00321875$$

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)

-----  
 $\phi_{sh,x}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$$L_{stir}(\text{Length of stirrups along Y}) = 1460.00$$

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

$$A_{sec}(\text{section area}) = 237500.00$$

-----  
 $\phi_{sh,y}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$$L_{stir}(\text{Length of stirrups along X}) = 1460.00$$

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

$$A_{sec}(\text{section area}) = 237500.00$$

-----  
 $s = 150.00$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

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

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

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$f_{t1} = 466.8167$$

$$f_{y1} = 389.0139$$

su1 = 0.00512

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

lo/lou,min = lb/d = 0.30

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

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

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

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

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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

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

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

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

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

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

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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

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

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

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

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0292549

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.06161259

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.05452049

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 33.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.03435585

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.07235549

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.0640268

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.15465327

Mu = MRc (4.14) = 2.9011E+008

u = su (4.1) = 1.0873764E-005

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 499423.877$

Calculation of Shear Strength at edge 1,  $V_{r1} = 515022.351$

$V_{r1} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{\text{Col}0}$

$V_{\text{Col}0} = 515022.351$

$k_{nl} = 1$  (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)

$f_c' = 33.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.90582$

$\mu_u = 470.1368$

$V_u = 0.33706551$

$d = 0.8 * h = 480.00$

$N_u = 8883.863$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$

where:

$V_{s1} = 116356.214$  is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 150.00$

$V_{s1}$  is multiplied by  $\text{Col}1 = 1.00$

$s/d = 0.75$

$V_{s2} = 279254.914$  is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 150.00$

$V_{s2}$  is multiplied by  $\text{Col}2 = 1.00$

$s/d = 0.3125$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 0.00$

From (11-11), ACI 440:  $V_s + V_f \leq 457936.196$

$b_w = 250.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 499423.877$

$V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{\text{Col}0}$

$V_{\text{Col}0} = 499423.877$

$k_{nl} = 1$  (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)

$f_c' = 33.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 3.34244$

$\mu_u = 540.7776$

$V_u = 0.33706551$

$d = 0.8 * h = 480.00$

$N_u = 8883.863$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$

where:

$V_{s1} = 116356.214$  is calculated for section web, with:

$d = 200.00$

Av = 157079.633

fy = 555.56

s = 150.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.75

Vs2 = 279254.914 is calculated for section flange, with:

d = 480.00

Av = 157079.633

fy = 555.56

s = 150.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.3125

Vf ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: Vs + Vf <= 457936.196

bw = 250.00

-----  
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, = 0.86

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

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

Consequently:

New material of Primary Member: Concrete Strength, fc = fcm = 33.00

New material of Primary Member: Steel Strength, fs = fsm = 555.56

Concrete Elasticity, Ec = 26999.444

Steel Elasticity, Es = 200000.00

Max Height, Hmax = 600.00

Min Height, Hmin = 250.00

Max Width, Wmax = 600.00

Min Width, Wmin = 250.00

Cover Thickness, c = 25.00

Element Length, L = 3000.00

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with lb/d = 0.30

No FRP Wrapping

-----  
Stepwise Properties

Bending Moment, M = -1.0386E+007

Shear Force, V2 = -3387.623

Shear Force, V3 = 217.5031

Axial Force, F = -9591.168

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: Aslt = 0.00

-Compression: Asc = 4121.77

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

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{R} = 1.0$   $u = 0.00632063$   
 $u = y + p = 0.00632063$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00632063$  ((4.29), Biskinis Phd))  
 $M_y = 3.3303E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3066.001  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 5.3849E+013$   
factor = 0.30  
 $A_g = 237500.00$   
 $f_c' = 33.00$   
 $N = 9591.168$   
 $E_c * I_g = 1.7950E+014$

Calculation of Yielding Moment  $M_y$

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

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 4.3407598E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / d)^{2/3}) = 311.2112$   
 $d = 557.00$   
 $y = 0.35641753$   
 $A = 0.0298211$   
 $B = 0.01920334$   
with  $pt = 0.01254381$   
 $pc = 0.00595605$   
 $pv = 0.01109992$   
 $N = 9591.168$   
 $b = 250.00$   
 $" = 0.07719928$   
 $y_{comp} = 1.1116859E-005$   
with  $f_c = 33.00$   
 $E_c = 26999.444$   
 $y = 0.35529928$   
 $A = 0.02944325$   
 $B = 0.01898202$   
with  $E_s = 200000.00$

Calculation of ratio  $l_b / d$

Inadequate Lap Length with  $l_b / d = 0.30$

- Calculation of  $p$  -

From table 10-8:  $p = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because  $l_b / d \geq 1$   
shear control ratio  $V_y E / V_{col} O E = 0.71876765$   
 $d = 557.00$   
 $s = 0.00$   
 $t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$   
 $A_v = 78.53982$ , is the area of every stirrup  
 $L_{stir} = 1460.00$ , 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.

$$NUD = 9591.168$$

$$Ag = 237500.00$$

$$f_{cE} = 33.00$$

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

$$pl = \text{Area\_Tot\_Long\_Rein}/(b*d) = 0.02959978$$

$$b = 250.00$$

$$d = 557.00$$

$$f_{cE} = 33.00$$

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

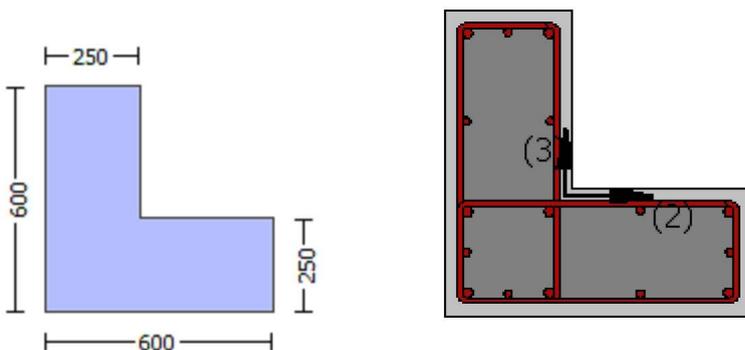
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (2)



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

At local axis: 2

Integration Section: (b)

Section Type: rclcs

Constant Properties

Knowledge Factor,  $\gamma = 0.86$

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

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

Consequently:

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

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
#####  
Note: Especially for the calculation of  $\gamma$  for displacement ductility demand,  
the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as  
Deformation-Controlled Action (Table C7-1, ASCE41-17).  
New material: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material: Steel Strength,  $f_s = f_{sm} = 555.56$   
#####  
Max Height,  $H_{max} = 600.00$   
Min Height,  $H_{min} = 250.00$   
Max Width,  $W_{max} = 600.00$   
Min Width,  $W_{min} = 250.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_o/l_{ou,min} = l_b/l_d = 0.30$   
No FRP Wrapping

-----  
Stepwise Properties

-----  
EDGE -A-  
Bending Moment,  $M_a = -1.0386E+007$   
Shear Force,  $V_a = -3387.623$   
EDGE -B-  
Bending Moment,  $M_b = 220916.627$   
Shear Force,  $V_b = 3387.623$   
BOTH EDGES  
Axial Force,  $F = -9591.168$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 4121.77$   
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,  $Db_{L,ten} = 17.71429$

-----  
New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 507421.609$   
 $V_n ((10.3), ASCE 41-17) = k_n \cdot V_{CoI0} = 507421.609$   
 $V_{CoI} = 507421.609$   
 $k_n = 1.00$   
displacement\_ductility\_demand = 0.04924536

-----  
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)  
 $f'_c = 25.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $M_u = 220916.627$   
 $V_u = 3387.623$   
 $d = 0.8 \cdot h = 480.00$   
 $N_u = 9591.168$   
 $A_g = 150000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 356047.167$   
where:  
 $V_{s1} = 104719.755$  is calculated for section web, with:

$d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 150.00$   
 Vs1 is multiplied by Col1 = 1.00  
 $s/d = 0.75$   
 Vs2 = 251327.412 is calculated for section flange, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 150.00$   
 Vs2 is multiplied by Col2 = 1.00  
 $s/d = 0.3125$   
 $V_f((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 398582.298$   
 $b_w = 250.00$

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 =  $3.0456129E-005$   
 $y = (M_y * L_s / 3) / E_{eff} = 0.00061846$  ((4.29), Biskinis Phd))  
 $M_y = 3.3303E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) =  $300.00$   
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 5.3849E+013$   
 $factor = 0.30$   
 $A_g = 237500.00$   
 $f_c' = 33.00$   
 $N = 9591.168$   
 $E_c * I_g = 1.7950E+014$

Calculation of Yielding Moment  $M_y$

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

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 4.3407598E-006$   
 with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 311.2112$   
 $d = 557.00$   
 $y = 0.35641753$   
 $A = 0.0298211$   
 $B = 0.01920334$   
 with  $p_t = 0.01254381$   
 $p_c = 0.00595605$   
 $p_v = 0.01109992$   
 $N = 9591.168$   
 $b = 250.00$   
 $\rho = 0.07719928$   
 $y_{comp} = 1.1116859E-005$   
 with  $f_c = 33.00$   
 $E_c = 26999.444$   
 $y = 0.35529928$   
 $A = 0.02944325$   
 $B = 0.01898202$   
 with  $E_s = 200000.00$

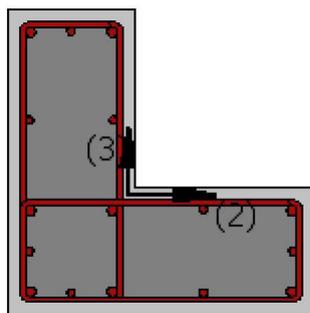
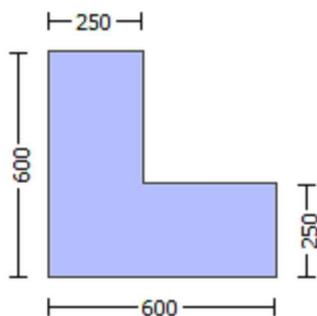
Calculation of ratio  $I_b / I_d$

Inadequate Lap Length with  $I_b / I_d = 0.30$

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

## Calculation No. 6

column C1, Floor 1  
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)  
Analysis: Uniform +X  
Check: Chord rotation capacity (  $\theta$  )  
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,  $\gamma = 0.86$

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

Consequently:

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

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

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

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.00  
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_o/l_{o,min} = 0.30$   
No FRP Wrapping

-----  
Stepwise Properties  
-----

At local axis: 3  
EDGE -A-  
Shear Force,  $V_a = 0.33706551$   
EDGE -B-  
Shear Force,  $V_b = -0.33706551$   
BOTH EDGES  
Axial Force,  $F = -8883.863$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 4121.77$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten} = 1746.726$   
-Compression:  $A_{sc,com} = 829.3805$   
-Middle:  $A_{st,mid} = 1545.664$   
-----  
-----

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.71876853$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 358969.728$   
with  
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 5.3845E+008$   
 $M_{u1+} = 5.3845E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination  
 $M_{u1-} = 2.9011E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 5.3845E+008$   
 $M_{u2+} = 5.3845E+008$ , 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  
 $M_{u2-} = 2.9011E+008$ , 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:  
 $\phi_u = 1.2895006E-005$   
 $M_u = 5.3845E+008$   
-----

with full section properties:

$b = 250.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00193327$   
 $N = 8883.863$   
 $f_c = 33.00$   
 $\phi_o$  (5A.5, TBDY) = 0.002  
Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_o) = 0.00616264$   
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY:  $\phi_u = 0.00616264$

$$w_e (5.4c) = 0.00443103$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1460.00$$

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

$$A_{sec} (\text{section area}) = 237500.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along X}) = 1460.00$$

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

$$A_{sec} (\text{section area}) = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

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

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

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

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

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

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

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

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

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

$$\text{with } fs_1 = fs = 389.0139$$

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

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$su_2 = 0.00512$$

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

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

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

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

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

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

$$\text{with } fs_2 = fs = 389.0139$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$f_{yv} = 389.0139$   
 $s_{uv} = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.30$   
 $s_{uv} = 0.4 * e_{suv\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $e_{suv\_nominal} = 0.08$ ,  
 considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $e_{suv\_nominal}$  and  $\gamma_v$ ,  $sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $\gamma_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $f_{sv} = f_s = 389.0139$   
 with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.14787021$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07021175$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.13084918$

and confined core properties:

$b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 33.00$   
 $cc (5A.5, TBDY) = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.20564193$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09764293$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.18197092$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---

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

---

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

---

$su (4.8) = 0.28715809$

$Mu = MR_c (4.15) = 5.3845E+008$

$u = su (4.1) = 1.2895006E-005$

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

-----  
 Inadequate Lap Length with  $l_b/l_d = 0.30$   
 -----  
 -----

-----  
 Calculation of  $Mu_1$ -  
 -----

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

$u = 1.0873764E-005$

$Mu = 2.9011E+008$

-----  
 with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00080553$

$N = 8883.863$

$f_c = 33.00$

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

Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00616264$

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

From (5.4b), TBDY:  $cu = 0.00616264$

$w_e (5.4c) = 0.00443103$

$ase = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

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) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $p_{sh,y}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $s = 150.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

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

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

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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

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

Shear\_factor = 1.00

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

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

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

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

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

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

with  $fs_1 = fs = 389.0139$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

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

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

Shear\_factor = 1.00

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

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

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

For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered

characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.

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

with  $fs_2 = fs = 389.0139$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$su_v = 0.00512$

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

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

Shear\_factor = 1.00

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

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

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

considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY

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

$\gamma_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $f_{sv} = f_s = 389.0139$

with  $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.0292549$

$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.06161259$

$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.05452049$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

$f_{cc}$  (5A.2, TBDY) = 33.00

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

$c$  = confinement factor = 1.00

$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.03435585$

$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.07235549$

$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.0640268$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---

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

---

$s_u$  (4.9) = 0.15465327

$M_u = M_{Rc}$  (4.14) = 2.9011E+008

$u = s_u$  (4.1) = 1.0873764E-005

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $M_{u2+}$

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

$u = 1.2895006E-005$

$M_u = 5.3845E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00193327$

$N = 8883.863$

$f_c = 33.00$

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

Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, cc) = 0.00616264$

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

From (5.4b), TBDY:  $c_u = 0.00616264$

$w_e$  (5.4c) = 0.00443103

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

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)

-----  
 $p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $s = 150.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

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

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

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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

$l_0/l_{ou,min} = l_b/l_d = 0.30$

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

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

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

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

with  $fs_1 = fs = 389.0139$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

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

$l_0/l_{ou,min} = l_b/l_{b,min} = 0.30$

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

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

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

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

with  $fs_2 = fs = 389.0139$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$su_v = 0.00512$

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

$l_0/l_{ou,min} = l_b/l_d = 0.30$

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

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  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $fy_v$ , it is considered characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

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

with  $f_{sv} = f_s = 389.0139$

with  $E_{sv} = E_s = 200000.00$

1 =  $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.14787021$

2 =  $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.07021175$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.13084918$

and confined core properties:

$b = 190.00$

$d = 527.00$

$d' = 13.00$

$f_{cc}$  (5A.2, TBDY) = 33.00

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

$c$  = confinement factor = 1.00

1 =  $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.20564193$

2 =  $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09764293$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.18197092$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

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

---->

$s_u$  (4.8) = 0.28715809

$M_u = M_{Rc}$  (4.15) = 5.3845E+008

$u = s_u$  (4.1) = 1.2895006E-005

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $M_u2$

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

$u = 1.0873764E-005$

$M_u = 2.9011E+008$

with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00080553$

$N = 8883.863$

$f_c = 33.00$

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

Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} \cdot \text{Max}(c_u, cc) = 0.00616264$

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

From (5.4b), TBDY:  $c_u = 0.00616264$

$w_e$  (5.4c) = 0.00443103

$ase = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) \cdot (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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 = 105733.333 is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00321875$

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)

-----  
 $psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $s = 150.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

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

$c =$  confinement factor = 1.00

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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

$lo/lo_{min} = lb/l_d = 0.30$

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

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

with  $fs_1 = fs = 389.0139$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

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

$lo/lo_{min} = lb/l_{b,min} = 0.30$

$su_2 = 0.4 * esu_{2\_nominal} \text{ ((5.5), TBDY)} = 0.032$

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

with  $fs_2 = fs = 389.0139$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$su_v = 0.00512$

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

$lo/lo_{min} = lb/l_d = 0.30$

$su_v = 0.4 * esu_{v\_nominal} \text{ ((5.5), TBDY)} = 0.032$

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

considering characteristic value  $fsy_v = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esu_{v\_nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered

characteristic value  $fsy_v = fsv/1.2$ , from table 5.1, TBDY.

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

with  $fsv = fs = 389.0139$

with  $Esv = Es = 200000.00$

$1 = Asl,ten/(b \cdot d) \cdot (fs_1/fc) = 0.0292549$

$2 = Asl,com/(b \cdot d) \cdot (fs_2/fc) = 0.06161259$

$v = Asl,mid/(b \cdot d) \cdot (fsv/fc) = 0.05452049$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 33.00$

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

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

$1 = Asl,ten/(b \cdot d) \cdot (fs_1/fc) = 0.03435585$

$2 = Asl,com/(b \cdot d) \cdot (fs_2/fc) = 0.07235549$

$v = Asl,mid/(b \cdot d) \cdot (fsv/fc) = 0.0640268$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---

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

---

$su (4.9) = 0.15465327$

$Mu = MRc (4.14) = 2.9011E+008$

$u = su (4.1) = 1.0873764E-005$

-----  
Calculation of ratio  $lb/d$

-----  
Inadequate Lap Length with  $lb/d = 0.30$   
-----  
-----  
-----

-----  
Calculation of Shear Strength  $Vr = \text{Min}(Vr_1, Vr_2) = 499423.271$   
-----

Calculation of Shear Strength at edge 1,  $Vr_1 = 515023.161$

$Vr_1 = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{Col0}$

$V_{Col0} = 515023.161$

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

-----  
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)

$fc' = 33.00$ , but  $fc^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$M/Vd = 2.9058$

$Mu = 470.1336$

$Vu = 0.33706551$

$d = 0.8 \cdot h = 480.00$

$Nu = 8883.863$

$Ag = 150000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$

where:

$V_{s1} = 279254.914$  is calculated for section web, with:

$d = 480.00$

$Av = 157079.633$

$fy = 555.56$

$s = 150.00$

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

$s/d = 0.3125$

$V_{s2} = 116356.214$  is calculated for section flange, with:

$d = 200.00$

$Av = 157079.633$

$fy = 555.56$

$s = 150.00$

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

$s/d = 0.75$

Vf ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440: Vs + Vf <= 457936.196  
bw = 250.00

-----  
Calculation of Shear Strength at edge 2, Vr2 = 499423.271  
Vr2 = VCol ((10.3), ASCE 41-17) = knl\*VCol0  
VCol0 = 499423.271  
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' = 33.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)  
M/Vd = 3.34246  
Mu = 540.7808  
Vu = 0.33706551  
d = 0.8\*h = 480.00  
Nu = 8883.863  
Ag = 150000.00  
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 395611.129

where:

Vs1 = 279254.914 is calculated for section web, with:

d = 480.00  
Av = 157079.633  
fy = 555.56  
s = 150.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.3125

Vs2 = 116356.214 is calculated for section flange, with:

d = 200.00  
Av = 157079.633  
fy = 555.56  
s = 150.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.75

Vf ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: Vs + Vf <= 457936.196

bw = 250.00

-----  
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, = 0.86

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

Consequently:

New material of Primary Member: Concrete Strength, fc = fcm = 33.00

New material of Primary Member: Steel Strength, fs = fsm = 555.56

Concrete Elasticity, Ec = 26999.444

Steel Elasticity, Es = 200000.00

#####

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

New material: Steel Strength, fs = 1.25\*fsm = 694.45

#####

Max Height, Hmax = 600.00  
Min Height, Hmin = 250.00  
Max Width, Wmax = 600.00  
Min Width, Wmin = 250.00  
Cover Thickness, c = 25.00  
Mean Confinement Factor overall section = 1.00  
Element Length, L = 3000.00  
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_o/l_{o,min} = 0.30$   
No FRP Wrapping

-----  
Stepwise Properties  
-----

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = 0.33706551$   
EDGE -B-  
Shear Force,  $V_b = -0.33706551$   
BOTH EDGES  
Axial Force,  $F = -8883.863$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 4121.77$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{s,ten} = 1746.726$   
-Compression:  $A_{s,com} = 829.3805$   
-Middle:  $A_{s,mid} = 1545.664$

-----  
-----  
Calculation of Shear Capacity ratio,  $V_e/V_r = 0.71876765$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 358969.728$   
with  
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 5.3845E+008$   
 $\mu_{u1+} = 5.3845E+008$ , 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  
 $\mu_{u1-} = 2.9011E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 5.3845E+008$   
 $\mu_{u2+} = 5.3845E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination  
 $\mu_{u2-} = 2.9011E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

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Calculation of  $\mu_{u1+}$   
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Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\phi_u = 1.2895006E-005$   
 $M_u = 5.3845E+008$

-----  
with full section properties:

b = 250.00  
d = 557.00  
d' = 43.00  
v = 0.00193327  
N = 8883.863  
f<sub>c</sub> = 33.00

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.00616264$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.00616264$$

$$w_e \text{ (5.4c)} = 0.00443103$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

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)

$$p_{sh,x} \text{ (5.4d), TBDY} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

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

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ (5.4d), TBDY} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

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

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

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

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

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

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

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

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

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

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

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

$$\text{with } fs_1 = fs = 389.0139$$

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

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$su_2 = 0.00512$$

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

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

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

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

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

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

$$\text{with } fs_2 = fs = 389.0139$$

with  $E_s = E_s = 200000.00$   
 $y_v = 0.00140044$   
 $sh_v = 0.0044814$   
 $ft_v = 466.8167$   
 $fy_v = 389.0139$   
 $suv = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou, min = lb/ld = 0.30$   
 $suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fsv = fs = 389.0139$   
 with  $Esv = Es = 200000.00$   
 $1 = Asl, ten / (b * d) * (fs1 / fc) = 0.14787021$   
 $2 = Asl, com / (b * d) * (fs2 / fc) = 0.07021175$   
 $v = Asl, mid / (b * d) * (fsv / fc) = 0.13084918$

and confined core properties:

$b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 33.00$   
 $cc (5A.5, TBDY) = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = Asl, ten / (b * d) * (fs1 / fc) = 0.20564193$   
 $2 = Asl, com / (b * d) * (fs2 / fc) = 0.09764293$   
 $v = Asl, mid / (b * d) * (fsv / fc) = 0.18197092$

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

--->  
 $v < vs, y2$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < vs, c$  - RHS eq.(4.5) is satisfied  
 --->  
 $su (4.8) = 0.28715809$   
 $Mu = MRc (4.15) = 5.3845E+008$   
 $u = su (4.1) = 1.2895006E-005$

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

-----  
 Inadequate Lap Length with  $lb/ld = 0.30$   
 -----  
 -----  
 -----

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

-----  
 Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 1.0873764E-005$   
 $Mu = 2.9011E+008$   
 -----

with full section properties:

$b = 600.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00080553$   
 $N = 8883.863$   
 $fc = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00616264$   
 The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $c_u = 0.00616264$

$w_e$  (5.4c) = 0.00443103

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

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) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

$p_{sh,y}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

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

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

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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

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

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

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

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

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

with  $fs_1 = fs = 389.0139$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

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

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

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

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

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

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

with  $fs_2 = fs = 389.0139$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

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

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

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

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

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

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

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

$$\text{with } fsv = fs = 389.0139$$

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

$$1 = Asl_{ten}/(b*d)*(fs1/fc) = 0.0292549$$

$$2 = Asl_{com}/(b*d)*(fs2/fc) = 0.06161259$$

$$v = Asl_{mid}/(b*d)*(fsv/fc) = 0.05452049$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 33.00$$

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

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

$$1 = Asl_{ten}/(b*d)*(fs1/fc) = 0.03435585$$

$$2 = Asl_{com}/(b*d)*(fs2/fc) = 0.07235549$$

$$v = Asl_{mid}/(b*d)*(fsv/fc) = 0.0640268$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---

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

---

$$su (4.9) = 0.15465327$$

$$Mu = MRc (4.14) = 2.9011E+008$$

$$u = su (4.1) = 1.0873764E-005$$

Calculation of ratio  $lb/d$

Inadequate Lap Length with  $lb/d = 0.30$

Calculation of  $Mu_{2+}$

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

$$u = 1.2895006E-005$$

$$Mu = 5.3845E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00193327$$

$$N = 8883.863$$

$$fc = 33.00$$

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

$$\text{Final value of } cu: cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00616264$$

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

$$\text{From (5.4b), TBDY: } cu = 0.00616264$$

$$we (5.4c) = 0.00443103$$

$$ase = \text{Max}(((Aconf_{max} - Aconf) / Aconf_{max}) * (Aconf_{min} / Aconf_{max}), 0) = 0.21805635$$

The definitions of  $Aconf_{min}$ ,  $Aconf$ , 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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00321875$

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)

-----  
 $psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $s = 150.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

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

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

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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

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

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

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

with  $fs_1 = fs = 389.0139$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

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

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

$su_2 = 0.4 * esu_{2\_nominal} \text{ ((5.5), TBDY)} = 0.032$

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

with  $fs_2 = fs = 389.0139$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$su_v = 0.00512$

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

Shear\_factor = 1.00

lo/lou,min = lb/d = 0.30

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

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

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

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

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

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.14787021

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.07021175

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.13084918

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 33.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.20564193

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.09764293

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.18197092

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

----

v < vs,y2 - LHS eq.(4.5) is not satisfied

----

v < vs,c - RHS eq.(4.5) is satisfied

----

su (4.8) = 0.28715809

Mu = MRc (4.15) = 5.3845E+008

u = su (4.1) = 1.2895006E-005

-----  
Calculation of ratio lb/d

-----  
Inadequate Lap Length with lb/d = 0.30  
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-----

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

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

u = 1.0873764E-005

Mu = 2.9011E+008  
-----

with full section properties:

b = 600.00

d = 557.00

d' = 43.00

v = 0.00080553

N = 8883.863

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.00616264

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

From (5.4b), TBDY: cu = 0.00616264

we (5.4c) = 0.00443103

ase =  $\text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0)$  = 0.21805635

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 = 169100.00 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 = 98400.00 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 = 105733.333 is the unconfined core area which is equal to  $b^2/6$  as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00321875

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) = 0.00321875

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 150.00

fywe = 694.45

fce = 33.00

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

c = confinement factor = 1.00

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

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

lo/lou,min = lb/lb = 0.30

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

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

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

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

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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

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

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

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

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

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

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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

lo/lou,min = lb/lb = 0.30

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

From table 5A.1, TBDY:  $e_{suv\_nominal} = 0.08$ ,  
considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY  
For calculation of  $e_{suv\_nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

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

with  $f_{sv} = f_s = 389.0139$

with  $E_{sv} = E_s = 200000.00$

1 =  $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0292549$

2 =  $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.06161259$

v =  $A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.05452049$

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

f<sub>cc</sub> (5A.2, TBDY) = 33.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 =  $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03435585$

2 =  $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.07235549$

v =  $A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.0640268$

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

--->

v < v<sub>s,y2</sub> - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.15465327

Mu = MRc (4.14) = 2.9011E+008

u = su (4.1) = 1.0873764E-005

-----  
Calculation of ratio lb/d

-----  
Inadequate Lap Length with lb/d = 0.30  
-----  
-----  
-----

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 499423.877$   
-----

Calculation of Shear Strength at edge 1,  $V_{r1} = 515022.351$

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

$V_{Col0} = 515022.351$

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

-----  
NOTE: In expression (10-3) 'V<sub>s</sub>' is replaced by 'V<sub>s+</sub> f\*V<sub>f</sub>'  
where V<sub>f</sub> is the contribution of FRPs (11.3), ACI 440).  
-----

= 1 (normal-weight concrete)

f<sub>c</sub>' = 33.00, but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.90582

Mu = 470.1368

Vu = 0.33706551

d = 0.8\*h = 480.00

Nu = 8883.863

Ag = 150000.00

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$

where:

$V_{s1} = 116356.214$  is calculated for section web, with:

d = 200.00

$A_v = 157079.633$

$f_y = 555.56$

s = 150.00

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

s/d = 0.75

$V_{s2} = 279254.914$  is calculated for section flange, with:

d = 480.00

$A_v = 157079.633$

$f_y = 555.56$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.3125$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440:  $V_s + V_f \leq 457936.196$   
 $bw = 250.00$

-----  
Calculation of Shear Strength at edge 2,  $V_{r2} = 499423.877$   
 $V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_n l * V_{Col0}$   
 $V_{Col0} = 499423.877$   
 $k_n l = 1$  (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)  
 $f_c' = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 3.34244$   
 $M_u = 540.7776$   
 $V_u = 0.33706551$   
 $d = 0.8 * h = 480.00$   
 $N_u = 8883.863$   
 $A_g = 150000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$   
where:  
 $V_{s1} = 116356.214$  is calculated for section web, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.75$   
 $V_{s2} = 279254.914$  is calculated for section flange, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.3125$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440:  $V_s + V_f \leq 457936.196$   
 $bw = 250.00$

-----  
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: rdc

Constant Properties

-----  
Knowledge Factor,  $\phi = 0.86$   
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.  
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$

Max Height, Hmax = 600.00  
Min Height, Hmin = 250.00  
Max Width, Wmax = 600.00  
Min Width, Wmin = 250.00  
Cover Thickness, c = 25.00  
Element Length, L = 3000.00  
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
No FRP Wrapping

#### Stepwise Properties

Bending Moment, M = -178244.622  
Shear Force, V2 = 3387.623  
Shear Force, V3 = -217.5031  
Axial Force, F = -9591.168  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 4121.77$   
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,  $D_bL = 17.71429$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0^*$   $u = 0.00168943$   
 $u = y + p = 0.00168943$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00168943$  ((4.29), Biskinis Phd)  
 $M_y = 3.3303E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 819.5039  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 5.3849E+013$   
factor = 0.30  
 $A_g = 237500.00$   
 $f_c' = 33.00$   
 $N = 9591.168$   
 $E_c * I_g = 1.7950E+014$

Calculation of Yielding Moment  $M_y$

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

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 4.3407598E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b/l_d)^{2/3}) = 311.2112$   
 $d = 557.00$   
 $y = 0.35641753$   
 $A = 0.0298211$   
 $B = 0.01920334$   
with  $pt = 0.01254381$   
 $pc = 0.00595605$   
 $pv = 0.01109992$   
 $N = 9591.168$   
 $b = 250.00$

" = 0.07719928  
y\_comp = 1.1116859E-005  
with fc = 33.00  
Ec = 26999.444  
y = 0.35529928  
A = 0.02944325  
B = 0.01898202  
with Es = 200000.00

-----  
-----  
Calculation of ratio lb/d

-----  
Inadequate Lap Length with lb/d = 0.30

-----  
- Calculation of p -

-----  
From table 10-8: p = 0.00

with:

- Columns not controlled by inadequate development or splicing along the clear height because lb/d >= 1  
shear control ratio  $V_yE/V_{CoIE} = 0.71876853$

d = 557.00

s = 0.00

$t = A_v/(b_w*s) + 2*tf/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*tf/b_w*(f_{fe}/f_s) = 0.00$

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

$L_{stir} = 1460.00$ , is the total Length of all stirrups parallel to loading (shear) direction

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

where  $f = 2*tf/b_w$  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 = 9591.168

$A_g = 237500.00$

$f_{cE} = 33.00$

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

$p_l = \text{Area\_Tot\_Long\_Rein}/(b*d) = 0.02959978$

b = 250.00

d = 557.00

$f_{cE} = 33.00$

-----  
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

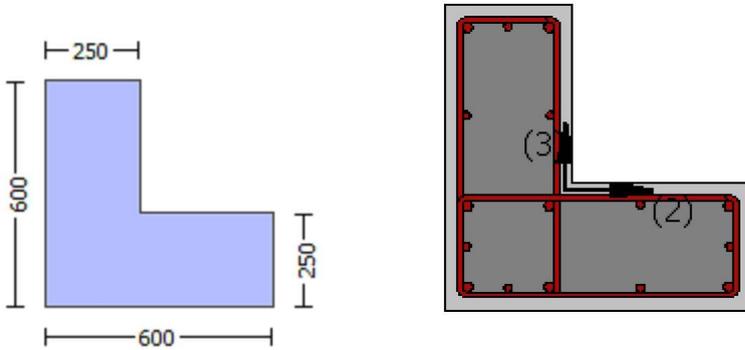
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (3)



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

At local axis: 3

Integration Section: (b)

Section Type: rclcs

Constant Properties

Knowledge Factor,  $\gamma = 0.86$

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

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

Consequently:

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

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

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

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

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with  $l_o/l_{ou,min} = l_b/l_d = 0.30$

No FRP Wrapping

Stepwise Properties

EDGE -A-

Bending Moment,  $M_a = -473533.503$

Shear Force,  $V_a = 217.5031$

EDGE -B-

Bending Moment,  $M_b = -178244.622$

Shear Force,  $V_b = -217.5031$

BOTH EDGES

Axial Force,  $F = -9591.168$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $A_{sc} = 4121.77$

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,  $D_{bL,ten} = 17.71429$

New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 507421.609$

$V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{CoIO} = 507421.609$

$V_{CoI} = 507421.609$

$k_n = 1.00$

displacement\_ductility\_demand =  $9.4631901E-006$

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)

$f'_c = 25.00$ , but  $f_c^{0.5} \leq 8.3$  MPa ((22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 178244.622$

$V_u = 217.5031$

$d = 0.8 \cdot h = 480.00$

$N_u = 9591.168$

$A_g = 150000.00$

From ((11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 356047.167$

where:

$V_{s1} = 251327.412$  is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 150.00$

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

$s/d = 0.3125$

$V_{s2} = 104719.755$  is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 150.00$

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

$s/d = 0.75$

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

From ((11-11), ACI 440:  $V_s + V_f \leq 398582.298$

$b_w = 250.00$

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 =  $1.5987359E-008$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00168943$  ((4.29), Biskinis Phd))

$M_y = 3.3303E+008$

$L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 819.5039  
From table 10.5, ASCE 41\_17:  $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 5.3849E+013$   
factor = 0.30  
Ag = 237500.00  
fc' = 33.00  
N = 9591.168  
 $E_c \cdot I_g = 1.7950E+014$

-----  
-----  
Calculation of Yielding Moment  $M_y$

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

-----  
 $y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$   
 $y_{\text{ten}} = 4.3407598E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b/I_d)^{2/3}) = 311.2112$   
d = 557.00  
y = 0.35641753  
A = 0.0298211  
B = 0.01920334  
with pt = 0.01254381  
pc = 0.00595605  
pv = 0.01109992  
N = 9591.168  
b = 250.00  
" = 0.07719928  
 $y_{\text{comp}} = 1.1116859E-005$   
with fc = 33.00  
Ec = 26999.444  
y = 0.35529928  
A = 0.02944325  
B = 0.01898202  
with Es = 200000.00

-----  
-----  
Calculation of ratio  $I_b/I_d$

-----  
Inadequate Lap Length with  $I_b/I_d = 0.30$

-----  
End Of Calculation of Shear Capacity for element: column LC1 of floor 1  
At local axis: 3  
Integration Section: (b)

-----  
**Calculation No. 8**

column C1, Floor 1

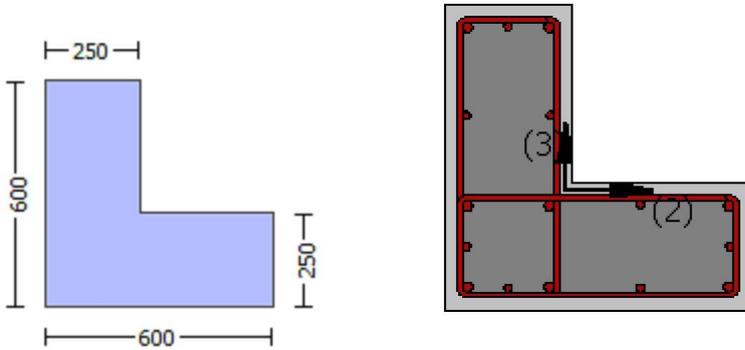
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\theta_u$ )

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: rclcs

Constant Properties

Knowledge Factor,  $\gamma = 0.86$

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

Consequently:

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

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

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

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with  $l_o/l_{ou,min} = 0.30$

No FRP Wrapping

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 0.33706551$   
EDGE -B-  
Shear Force,  $V_b = -0.33706551$   
BOTH EDGES  
Axial Force,  $F = -8883.863$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 4121.77$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten} = 1746.726$   
-Compression:  $A_{sc,com} = 829.3805$   
-Middle:  $A_{st,mid} = 1545.664$

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Calculation of Shear Capacity ratio,  $V_e/V_r = 0.71876853$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 358969.728$   
with  
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 5.3845E+008$   
 $Mu_{1+} = 5.3845E+008$ , 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  
 $Mu_{1-} = 2.9011E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 5.3845E+008$   
 $Mu_{2+} = 5.3845E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination  
 $Mu_{2-} = 2.9011E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

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Calculation of  $Mu_{1+}$   
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Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\phi_u = 1.2895006E-005$   
 $M_u = 5.3845E+008$

-----  
with full section properties:

$b = 250.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00193327$   
 $N = 8883.863$   
 $f_c = 33.00$   
 $\alpha_1 = 0.85$   
Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00616264$   
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY:  $\phi_u = 0.00616264$   
 $\phi_{c1} = 0.00443103$   
 $\phi_{c2} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$   
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.  
 $A_{conf,max} = 169100.00$  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.  
 $A_{conf,min} = 98400.00$  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.  
 $A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $\phi_{c3} = \text{Min}(\phi_{c3,x}, \phi_{c3,y}) = 0.00321875$   
Expression ((5.4d), TBDY) for  $\phi_{c3}$  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) =  $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) =  $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 150.00

fywe = 694.45

fce = 33.00

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

c = confinement factor = 1.00

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

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

lo/lou,min = lb/d = 0.30

su1 =  $0.4 \cdot esu1\_nominal$  ((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  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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

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

su2 =  $0.4 \cdot esu2\_nominal$  ((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  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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

lo/lou,min = lb/d = 0.30

suv =  $0.4 \cdot esuv\_nominal$  ((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  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 =  $Asl,ten / (b \cdot d) \cdot (fs1 / fc) = 0.14787021$

2 =  $Asl,com / (b \cdot d) \cdot (fs2 / fc) = 0.07021175$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.13084918$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.00$$

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

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.20564193$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09764293$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.18197092$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

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

--->

$$s_u (4.8) = 0.28715809$$

$$\mu_u = M R_c (4.15) = 5.3845E+008$$

$$u = s_u (4.1) = 1.2895006E-005$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{u1}$ -

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

$$u = 1.0873764E-005$$

$$\mu_u = 2.9011E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00080553$$

$$N = 8883.863$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.00616264$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.00616264$$

$$w_e (5.4c) = 0.00443103$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along } Y) = 1460.00$$

Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875  
Lstir (Length of stirrups along X) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

s = 150.00  
fywe = 694.45  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.002  
c = confinement factor = 1.00

y1 = 0.00140044  
sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

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

lo/lou,min = lb/d = 0.30

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

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

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

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

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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

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

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

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

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

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

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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

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

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

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

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

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0292549

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.06161259

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.05452049

and confined core properties:

b = 540.00

$d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 33.00$   
 $cc (5A.5, TBDY) = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03435585$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07235549$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0640268$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.15465327$   
 $Mu = MRc (4.14) = 2.9011E+008$   
 $u = su (4.1) = 1.0873764E-005$

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

-----  
 Inadequate Lap Length with  $l_b/l_d = 0.30$   
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 -----

-----  
 Calculation of  $Mu_{2+}$   
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-----  
 Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 1.2895006E-005$   
 $Mu = 5.3845E+008$   
 -----

with full section properties:

$b = 250.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00193327$   
 $N = 8883.863$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00616264$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.00616264$   
 $we (5.4c) = 0.00443103$

$ase = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

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)

-----  
 $p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00  
 -----

$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

s = 150.00

fywe = 694.45

fce = 33.00

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

c = confinement factor = 1.00

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

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

lo/lou,min = lb/lb = 0.30

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

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

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

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

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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

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

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

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

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

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

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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

lo/lou,min = lb/lb = 0.30

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

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

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

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

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

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.14787021

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.07021175

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.13084918

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 33.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.20564193$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09764293$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.18197092$$

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

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

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

--->  
 $\mu_u$  (4.8) = 0.28715809  
 $M_u = M_{Rc}$  (4.15) = 5.3845E+008  
 $u = \mu_u$  (4.1) = 1.2895006E-005

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{u2}$

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

$$u = 1.0873764E-005$$

$$M_u = 2.9011E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00080553$$

$$N = 8883.863$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_{cu} : \mu_{cu}^* = \text{shear\_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.00616264$$

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

$$\text{From (5.4b), TBDY: } \mu_{cu} = 0.00616264$$

$$\mu_{we} \text{ (5.4c)} = 0.00443103$$

$$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$$

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

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

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

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.00321875$$

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)

$$\mu_{psh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

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

$$A_{sec} \text{ (section area)} = 237500.00$$

$$\mu_{psh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

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

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

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

$c =$  confinement factor = 1.00

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

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

$$l_0/l_{ou,min} = l_b/l_d = 0.30$$

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

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

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

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

$$\text{with } fs_1 = fs = 389.0139$$

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

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$su_2 = 0.00512$$

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

$$l_0/l_{ou,min} = l_b/l_{b,min} = 0.30$$

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

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

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

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

$$\text{with } fs_2 = fs = 389.0139$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$su_v = 0.00512$$

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

$$l_0/l_{ou,min} = l_b/l_d = 0.30$$

$$su_v = 0.4 * esu_{v,nominal} ((5.5), TBDY) = 0.032$$

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

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

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

$$\text{with } fs_v = fs = 389.0139$$

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

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.0292549$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.06161259$$

$$v = Asl_{mid}/(b*d) * (fs_v/fc) = 0.05452049$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.00$$

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

$c =$  confinement factor = 1.00

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.03435585$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.07235549$$

$$v = Asl_{mid}/(b*d) * (fs_v/fc) = 0.0640268$$

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

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

--->  
 $s_u$  (4.9) = 0.15465327  
 $M_u = M_{Rc}$  (4.14) = 2.9011E+008  
 $u = s_u$  (4.1) = 1.0873764E-005

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

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
-----  
-----  
-----

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 499423.271$   
-----

Calculation of Shear Strength at edge 1,  $V_{r1} = 515023.161$   
 $V_{r1} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} * V_{Col0}$   
 $V_{Col0} = 515023.161$   
 $k_{nl} = 1$  (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)  
 $f_c' = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.9058$   
 $M_u = 470.1336$   
 $V_u = 0.33706551$   
 $d = 0.8 * h = 480.00$   
 $N_u = 8883.863$   
 $A_g = 150000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$   
where:  
 $V_{s1} = 279254.914$  is calculated for section web, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.3125$   
 $V_{s2} = 116356.214$  is calculated for section flange, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.75$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440:  $V_s + V_f \leq 457936.196$   
 $b_w = 250.00$   
-----

-----  
Calculation of Shear Strength at edge 2,  $V_{r2} = 499423.271$   
 $V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} * V_{Col0}$   
 $V_{Col0} = 499423.271$   
 $k_{nl} = 1$  (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)  
 $f_c' = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 3.34246$

$\mu_u = 540.7808$   
 $V_u = 0.33706551$   
 $d = 0.8 \cdot h = 480.00$   
 $N_u = 8883.863$   
 $A_g = 150000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$   
 where:  
 $V_{s1} = 279254.914$  is calculated for section web, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.3125$   
 $V_{s2} = 116356.214$  is calculated for section flange, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.75$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 457936.196$   
 $b_w = 250.00$

-----  
 -----  
 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,  $\phi = 0.86$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 #####  
 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  
 New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
 #####  
 Max Height,  $H_{max} = 600.00$   
 Min Height,  $H_{min} = 250.00$   
 Max Width,  $W_{max} = 600.00$   
 Min Width,  $W_{min} = 250.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.00  
 Element Length,  $L = 3000.00$   
 Primary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Inadequate Lap Length with  $l_o/l_{o,u,min} = 0.30$   
 No FRP Wrapping

## Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = 0.33706551$

EDGE -B-

Shear Force,  $V_b = -0.33706551$

BOTH EDGES

Axial Force,  $F = -8883.863$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $A_{sc} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{st,ten} = 1746.726$

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

-Middle:  $A_{st,mid} = 1545.664$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.71876765$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 358969.728$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 5.3845E+008$

$M_{u1+} = 5.3845E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.9011E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 5.3845E+008$

$M_{u2+} = 5.3845E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 2.9011E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of  $M_{u1+}$

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

$\phi_u = 1.2895006E-005$

$M_u = 5.3845E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00193327$

$N = 8883.863$

$f_c = 33.00$

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

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00616264$

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

From (5.4b), TBDY:  $\phi_u = 0.00616264$

$w_e$  (5.4c) = 0.00443103

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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 = 105733.333 is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00321875$

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)

-----  
 $psh_x \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00321875$

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

-----  
 $psh_y \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00321875$

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

-----  
 $s = 150.00$

$fy_{we} = 694.45$

$f_{ce} = 33.00$

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

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

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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

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

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

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

with  $fs_1 = fs = 389.0139$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

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

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

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

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

with  $fs_2 = fs = 389.0139$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$su_v = 0.00512$

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

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

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

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.

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

with  $f_{sv} = f_s = 389.0139$   
with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.14787021$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07021175$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.13084918$

and confined core properties:

$b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 33.00$   
 $cc (5A.5, TBDY) = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.20564193$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09764293$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.18197092$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

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

--->

$su (4.8) = 0.28715809$

$M_u = MR_c (4.15) = 5.3845E+008$

$u = su (4.1) = 1.2895006E-005$

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

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
-----  
-----

-----  
Calculation of  $Mu_1$ -  
-----

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

$u = 1.0873764E-005$

$M_u = 2.9011E+008$   
-----

with full section properties:

$b = 600.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00080553$   
 $N = 8883.863$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$

Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00616264$

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

From (5.4b), TBDY:  $cu = 0.00616264$

$w_e (5.4c) = 0.00443103$

$ase = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

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)

$$\text{psh}_x \text{ ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00321875$$

$$\text{Lstir (Length of stirrups along Y)} = 1460.00$$

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

$$\text{Asec (section area)} = 237500.00$$

$$\text{psh}_y \text{ ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00321875$$

$$\text{Lstir (Length of stirrups along X)} = 1460.00$$

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

$$\text{Asec (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

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

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

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

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

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

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

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

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

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

$$\text{with } fs_1 = fs = 389.0139$$

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

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$su_2 = 0.00512$$

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

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

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

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

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.

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

$$\text{with } fs_2 = fs = 389.0139$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$suv = 0.00512$$

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

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

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

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

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

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

$$\text{with } fsv = fs = 389.0139$$

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

$$1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.0292549$$

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.06161259$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.05452049$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.00$$

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

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03435585$$

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.07235549$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0640268$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.15465327$$

$$M_u = M_{Rc} (4.14) = 2.9011E+008$$

$$u = s_u (4.1) = 1.0873764E-005$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $M_{u2+}$

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

$$u = 1.2895006E-005$$

$$M_u = 5.3845E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00193327$$

$$N = 8883.863$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.00616264$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.00616264$$

$$w_e (5.4c) = 0.00443103$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along } Y) = 1460.00$$

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

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 150.00

fywe = 694.45

fce = 33.00

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

c = confinement factor = 1.00

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

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

lo/lou,min = lb/d = 0.30

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

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

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

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

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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

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

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

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

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

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

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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

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

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

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

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.14787021

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.07021175

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.13084918

and confined core properties:

b = 190.00

d = 527.00

$d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 33.00$   
 $cc (5A.5, TBDY) = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.20564193$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09764293$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.18197092$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

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

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

--->  
 $su (4.8) = 0.28715809$   
 $Mu = MRc (4.15) = 5.3845E+008$   
 $u = su (4.1) = 1.2895006E-005$

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

-----  
 Inadequate Lap Length with  $l_b/l_d = 0.30$   
 -----  
 -----

-----  
 Calculation of  $Mu_2$ -  
 -----  
 -----

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

$u = 1.0873764E-005$   
 $Mu = 2.9011E+008$

-----  
 with full section properties:

$b = 600.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00080553$   
 $N = 8883.863$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00616264$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.00616264$   
 $w_e (5.4c) = 0.00443103$

$ase = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

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)

-----  
 $p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00  
 -----

$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

Lstir (Length of stirrups along X) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

s = 150.00

fywe = 694.45

fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY  
For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0292549

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.06161259

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.05452049

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 33.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00  
1 =  $Asl,ten/(b*d)*(fs1/fc) = 0.03435585$   
2 =  $Asl,com/(b*d)*(fs2/fc) = 0.07235549$   
v =  $Asl,mid/(b*d)*(fsv/fc) = 0.0640268$

Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)

--->  
v <  $v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->  
su (4.9) = 0.15465327  
Mu = MRc (4.14) = 2.9011E+008  
u = su (4.1) = 1.0873764E-005

-----  
Calculation of ratio lb/ld

-----  
Inadequate Lap Length with lb/ld = 0.30  
-----  
-----  
-----

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 499423.877$   
-----

Calculation of Shear Strength at edge 1,  $V_{r1} = 515022.351$   
 $V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = knl * V_{Co10}$   
 $V_{Co10} = 515022.351$   
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)  
 $fc' = 33.00$ , but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.90582$   
Mu = 470.1368  
Vu = 0.33706551  
d = 0.8\*h = 480.00  
Nu = 8883.863  
Ag = 150000.00  
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$   
where:  
 $V_{s1} = 116356.214$  is calculated for section web, with:  
d = 200.00  
Av = 157079.633  
fy = 555.56  
s = 150.00  
 $V_{s1}$  is multiplied by Col1 = 1.00  
s/d = 0.75  
 $V_{s2} = 279254.914$  is calculated for section flange, with:  
d = 480.00  
Av = 157079.633  
fy = 555.56  
s = 150.00  
 $V_{s2}$  is multiplied by Col2 = 1.00  
s/d = 0.3125  
Vf ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440:  $V_s + V_f \leq 457936.196$   
bw = 250.00  
-----

-----  
Calculation of Shear Strength at edge 2,  $V_{r2} = 499423.877$   
 $V_{r2} = V_{Co2} ((10.3), ASCE 41-17) = knl * V_{Co10}$   
 $V_{Co10} = 499423.877$   
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)  
 $f_c' = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 3.34244$   
 $\mu_u = 540.7776$   
 $V_u = 0.33706551$   
 $d = 0.8 \cdot h = 480.00$   
 $N_u = 8883.863$   
 $A_g = 150000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$   
where:  
 $V_{s1} = 116356.214$  is calculated for section web, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.75$   
 $V_{s2} = 279254.914$  is calculated for section flange, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.3125$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440:  $V_s + V_f \leq 457936.196$   
 $b_w = 250.00$   
-----

-----  
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: rclcs

Constant Properties

-----  
Knowledge Factor,  $\gamma = 0.86$   
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.  
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Max Height,  $H_{max} = 600.00$   
Min Height,  $H_{min} = 250.00$   
Max Width,  $W_{max} = 600.00$   
Min Width,  $W_{min} = 250.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
No FRP Wrapping  
-----

Stepwise Properties

Bending Moment,  $M = 220916.627$   
Shear Force,  $V2 = 3387.623$   
Shear Force,  $V3 = -217.5031$   
Axial Force,  $F = -9591.168$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 4121.77$   
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,  $Db_L = 17.71429$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0^*$   $u = 0.00061846$   
 $u = y + p = 0.00061846$

- Calculation of  $y$  -

$y = (My * Ls / 3) / E_{eff} = 0.00061846$  ((4.29), Biskinis Phd))  
 $My = 3.3303E+008$   
 $Ls = M/V$  (with  $Ls > 0.1 * L$  and  $Ls < 2 * L$ ) = 300.00  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 5.3849E+013$   
 $factor = 0.30$   
 $Ag = 237500.00$   
 $fc' = 33.00$   
 $N = 9591.168$   
 $E_c * I_g = 1.7950E+014$

Calculation of Yielding Moment  $My$

Calculation of  $y$  and  $My$  according to Annex 7 -

$y = \text{Min}(y_{,ten}, y_{,com})$   
 $y_{,ten} = 4.3407598E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 311.2112$   
 $d = 557.00$   
 $y = 0.35641753$   
 $A = 0.0298211$   
 $B = 0.01920334$   
with  $pt = 0.01254381$   
 $pc = 0.00595605$   
 $pv = 0.01109992$   
 $N = 9591.168$   
 $b = 250.00$   
 $" = 0.07719928$   
 $y_{,comp} = 1.1116859E-005$   
with  $fc = 33.00$   
 $E_c = 26999.444$   
 $y = 0.35529928$   
 $A = 0.02944325$   
 $B = 0.01898202$   
with  $Es = 200000.00$

Calculation of ratio  $I_b / I_d$

Inadequate Lap Length with  $I_b / I_d = 0.30$

- Calculation of  $\rho$  -

From table 10-8:  $\rho = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because  $l_b/l_d \geq 1$

shear control ratio  $V_{yE}/V_{CoIE} = 0.71876765$

$d = 557.00$

$s = 0.00$

$t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.00$

$A_v = 78.53982$ , is the area of every stirrup

$L_{stir} = 1460.00$ , 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.

$NUD = 9591.168$

$A_g = 237500.00$

$f_{cE} = 33.00$

$f_{ytE} = f_{ylE} = 0.00$

$\rho_l = \text{Area\_Tot\_Long\_Rein}/(b*d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_{cE} = 33.00$

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

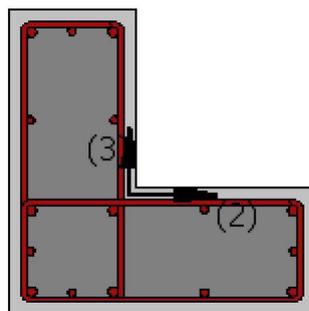
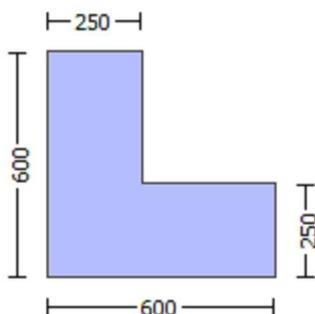
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rdcs

Constant Properties

Knowledge Factor,  $\gamma = 0.86$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of  $\gamma$  for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

New material: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material: Steel Strength,  $f_s = f_{sm} = 555.56$

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with  $l_o/l_{o,min} = l_b/l_d = 0.30$

No FRP Wrapping

Stepwise Properties

EDGE -A-

Bending Moment,  $M_a = -1.6331E+007$

Shear Force,  $V_a = -5326.433$

EDGE -B-

Bending Moment,  $M_b = 347029.948$

Shear Force,  $V_b = 5326.433$

BOTH EDGES

Axial Force,  $F = -9995.934$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $A_{sc} = 4121.77$

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,  $D_{bL,ten} = 17.71429$

New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 431774.345$

$V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{CoI} = 431774.345$

$V_{CoI} = 431774.345$

$k_n = 1.00$

displacement\_ductility\_demand = 0.01703446

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)

$f_c' = 25.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.6331E+007$

$V_u = 5326.433$

$d = 0.8 \cdot h = 480.00$

$N_u = 9995.934$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 356047.167$

where:

$V_{s1} = 104719.755$  is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 150.00$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$s/d = 0.75$

$V_{s2} = 251327.412$  is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 150.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.3125$

$V_f$  ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440:  $V_s + V_f \leq 398582.298$

$b_w = 250.00$

displacement ductility demand is calculated as  $\delta / y$

- Calculation of  $\delta / y$  for END A -  
for rotation axis 3 and integ. section (a)

From analysis, chord rotation = 0.00010769

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00632205$  ((4.29), Biskinis Phd)

$M_y = 3.3311E+008$

$L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 3065.941

From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 5.3849E+013$

factor = 0.30

$A_g = 237500.00$

$f_c' = 33.00$

$N = 9995.934$

$E_c \cdot I_g = 1.7950E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta / y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 4.3412800E-006$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 311.2112$

$d = 557.00$

$y = 0.35649464$

$A = 0.02983044$

$B = 0.01921269$

with  $pt = 0.01254381$

$pc = 0.00595605$

$pv = 0.01109992$

$N = 9995.934$

$b = 250.00$

$$\nu = 0.07719928$$

$$y_{comp} = 1.1115910E-005$$

with  $f_c = 33.00$

$$E_c = 26999.444$$

$$y = 0.3553296$$

$$A = 0.02943664$$

$$B = 0.01898202$$

with  $E_s = 200000.00$

Calculation of ratio  $I_b/I_d$

Inadequate Lap Length with  $I_b/I_d = 0.30$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (a)

## Calculation No. 10

column C1, Floor 1

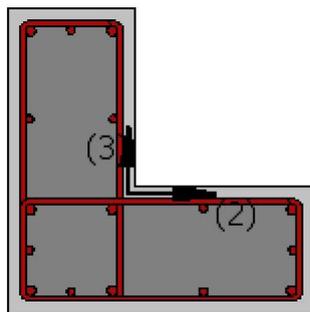
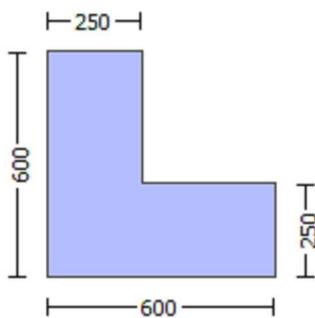
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\mu$ )

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rclcs

Constant Properties

Knowledge Factor,  $\nu = 0.86$

Mean strength values are used for both shear and moment calculations.

Consequently:

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

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

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with  $l_o/l_{ou,min} = 0.30$

No FRP Wrapping

-----  
Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 0.33706551$

EDGE -B-

Shear Force,  $V_b = -0.33706551$

BOTH EDGES

Axial Force,  $F = -8883.863$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{sl,t} = 0.00$

-Compression:  $A_{sl,c} = 4121.77$

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,  $V_e/V_r = 0.71876853$

Member Controlled by Flexure ( $V_e/V_r < 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 358969.728$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 5.3845E+008$

$M_{u1+} = 5.3845E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.9011E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 5.3845E+008$

$M_{u2+} = 5.3845E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 2.9011E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

-----  
Calculation of  $M_{u1+}$

-----  
Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

u = 1.2895006E-005  
Mu = 5.3845E+008

with full section properties:

b = 250.00

d = 557.00

d' = 43.00

v = 0.00193327

N = 8883.863

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.00616264

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.00616264

we (5.4c) = 0.00443103

ase = Max(((Aconf,max-AnoConf)/Aconf,max)\*(Aconf,min/Aconf,max),0) = 0.21805635

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 = 169100.00 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 = 98400.00 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 = 105733.333 is the unconfined core area which is equal to bi<sup>2</sup>/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00321875

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) = 0.00321875

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 150.00

fywe = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min = lb/d = 0.30

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/d)<sup>2/3</sup>), from 10.3.5, ASCE41-17.

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$$

$$s_u2 = 0.4 * e_{su2\_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{su2\_nominal} = 0.08$ ,

For calculation of  $e_{su2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } f_{s2} = f_s = 389.0139$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$s_{uv} = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$s_{uv} = 0.4 * e_{suv\_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{suv\_nominal} = 0.08$ ,

considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{suv\_nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } f_{sv} = f_s = 389.0139$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.14787021$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.07021175$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.13084918$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.00$$

$$cc (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.20564193$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.09764293$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.18197092$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$  - RHS eq.(4.5) is satisfied

--->

$$s_u (4.8) = 0.28715809$$

$$M_u = M_{Rc} (4.15) = 5.3845E+008$$

$$u = s_u (4.1) = 1.2895006E-005$$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
-----  
-----  
-----

-----  
Calculation of  $M_{u1}$ -  
-----  
-----  
-----

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0873764E-005$$

$$M_u = 2.9011E+008$$
  
-----

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00080553$$

$$N = 8883.863$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.00616264$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.00616264$$

$$w_e \text{ (5.4c)} = 0.00443103$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 0.30$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{1,nominal} = 0.08,$$

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1 / 1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 389.0139$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$su_2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$$

$$s_u2 = 0.4 * e_{s_u2\_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{s_u2\_nominal} = 0.08$ ,

For calculation of  $e_{s_u2\_nominal}$  and  $y_2$ ,  $sh_2, ft_2, fy_2$ , it is considered characteristic value  $f_{s_y2} = f_{s_2}/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } f_{s_2} = f_s = 389.0139$$

$$\text{with } E_{s_2} = E_s = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$s_{u_v} = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$s_{u_v} = 0.4 * e_{s_{u_v\_nominal}} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{s_{u_v\_nominal}} = 0.08$ ,

considering characteristic value  $f_{s_{y_v}} = f_{s_v}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{s_{u_v\_nominal}}$  and  $y_v$ ,  $sh_v, ft_v, fy_v$ , it is considered characteristic value  $f_{s_{y_v}} = f_{s_v}/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } f_{s_v} = f_s = 389.0139$$

$$\text{with } E_{s_v} = E_s = 200000.00$$

$$1 = A_{s_l,ten}/(b*d)*(f_{s_1}/f_c) = 0.0292549$$

$$2 = A_{s_l,com}/(b*d)*(f_{s_2}/f_c) = 0.06161259$$

$$v = A_{s_l,mid}/(b*d)*(f_{s_v}/f_c) = 0.05452049$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.00$$

$$cc (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = A_{s_l,ten}/(b*d)*(f_{s_1}/f_c) = 0.03435585$$

$$2 = A_{s_l,com}/(b*d)*(f_{s_2}/f_c) = 0.07235549$$

$$v = A_{s_l,mid}/(b*d)*(f_{s_v}/f_c) = 0.0640268$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.15465327$$

$$\mu_u = M_{Rc} (4.14) = 2.9011E+008$$

$$u = s_u (4.1) = 1.0873764E-005$$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
-----  
-----

-----  
Calculation of  $\mu_{u2+}$   
-----  
-----

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.2895006E-005$$

$$\mu_u = 5.3845E+008$$

-----  
with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00193327$$

$$N = 8883.863$$

$$f_c = 33.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.00616264$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.00616264$$

$$w_e (5.4c) = 0.00443103$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along X}) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$f_{t1} = 466.8167$$

$$f_{y1} = 389.0139$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.30$$

$$su_1 = 0.4 * esu1_{nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_{nominal} = 0.08,$$

For calculation of  $esu1_{nominal}$  and  $y_1, sh_1, f_{t1}, f_{y1}$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, f_{t1}, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 389.0139$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$f_{t2} = 466.8167$$

$$f_{y2} = 389.0139$$

$$su_2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$$

$$su_2 = 0.4 * esu2_{nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_{nominal} = 0.08,$$

For calculation of  $esu2_{nominal}$  and  $y_2, sh_2, f_{t2}, f_{y2}$ , 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, ASCE41-17.

with  $fs2 = fs = 389.0139$

with  $Es2 = Es = 200000.00$

$yv = 0.00140044$

$shv = 0.0044814$

$ftv = 466.8167$

$fyv = 389.0139$

$suv = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lou, \min = lb/ld = 0.30$

$suv = 0.4 \cdot esuv\_nominal ((5.5), TBDY) = 0.032$

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, ASCE41-17.

with  $fsv = fs = 389.0139$

with  $Es = Es = 200000.00$

1 =  $Asl, \text{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.14787021$

2 =  $Asl, \text{com} / (b \cdot d) \cdot (fs2 / fc) = 0.07021175$

v =  $Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.13084918$

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 33.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 =  $Asl, \text{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.20564193$

2 =  $Asl, \text{com} / (b \cdot d) \cdot (fs2 / fc) = 0.09764293$

v =  $Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.18197092$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs, y2$  - LHS eq.(4.5) is not satisfied

--->

$v < vs, c$  - RHS eq.(4.5) is satisfied

--->

$su$  (4.8) = 0.28715809

$Mu = MRc$  (4.15) = 5.3845E+008

u =  $su$  (4.1) = 1.2895006E-005

-----  
Calculation of ratio  $lb/ld$

-----  
Inadequate Lap Length with  $lb/ld = 0.30$   
-----  
-----

-----  
Calculation of  $Mu2$ -  
-----  
-----

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.0873764E-005$

$Mu = 2.9011E+008$   
-----

with full section properties:

b = 600.00

d = 557.00

d' = 43.00

v = 0.00080553

N = 8883.863

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00616264$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $cu = 0.00616264$

we (5.4c) = 0.00443103

$ase = \text{Max}(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.21805635$

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 = 169100.00 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 = 98400.00 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 = 105733.333 is the unconfined core area which is equal to  $bi^2/6$  as defined at (A.2).

$psh,min = \text{Min}(psh,x, psh,y) = 0.00321875$

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) =  $Lstir * Astir / (Asec * s) = 0.00321875$

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

-----  
 $psh,y$  ((5.4d), TBDY) =  $Lstir * Astir / (Asec * s) = 0.00321875$

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

-----  
 $s = 150.00$

$fywe = 694.45$

$fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.002$

$c = \text{confinement factor} = 1.00$

$y1 = 0.00140044$

$sh1 = 0.0044814$

$ft1 = 466.8167$

$fy1 = 389.0139$

$su1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lou,min = lb/d = 0.30$

$su1 = 0.4 * esu1\_nominal$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs1 = fs = 389.0139$

with  $Es1 = Es = 200000.00$

$y2 = 0.00140044$

$sh2 = 0.0044814$

$ft2 = 466.8167$

$fy2 = 389.0139$

$su2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lou,min = lb/lb,min = 0.30$

$su2 = 0.4 * esu2\_nominal$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs2 = fs = 389.0139$

with  $Es2 = Es = 200000.00$

yv = 0.00140044  
shv = 0.0044814  
ftv = 466.8167  
fyv = 389.0139  
suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.30

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/d)^2/3), from 10.3.5, ASCE41-17.

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0292549

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.06161259

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.05452049

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 33.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.03435585

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.07235549

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.0640268

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---

v < vs,y2 - LHS eq.(4.5) is satisfied

---

su (4.9) = 0.15465327

Mu = MRc (4.14) = 2.9011E+008

u = su (4.1) = 1.0873764E-005

-----  
Calculation of ratio lb/d

-----  
Inadequate Lap Length with lb/d = 0.30  
-----  
-----  
-----

-----  
Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 499423.271  
-----

-----  
Calculation of Shear Strength at edge 1, Vr1 = 515023.161

Vr1 = VCol ((10.3), ASCE 41-17) = knl\*VCol0

VCol0 = 515023.161

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' = 33.00, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.9058

Mu = 470.1336

Vu = 0.33706551

d = 0.8\*h = 480.00

Nu = 8883.863

Ag = 150000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 395611.129

where:

Vs1 = 279254.914 is calculated for section web, with:

d = 480.00

Av = 157079.633

fy = 555.56

s = 150.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.3125

Vs2 = 116356.214 is calculated for section flange, with:

d = 200.00

Av = 157079.633

fy = 555.56

s = 150.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.75

Vf ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: Vs + Vf <= 457936.196

bw = 250.00

Calculation of Shear Strength at edge 2, Vr2 = 499423.271

Vr2 = VCol ((10.3), ASCE 41-17) = knl\*VCol0

VCol0 = 499423.271

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' = 33.00, but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

M/Vd = 3.34246

Mu = 540.7808

Vu = 0.33706551

d = 0.8\*h = 480.00

Nu = 8883.863

Ag = 150000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 395611.129

where:

Vs1 = 279254.914 is calculated for section web, with:

d = 480.00

Av = 157079.633

fy = 555.56

s = 150.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.3125

Vs2 = 116356.214 is calculated for section flange, with:

d = 200.00

Av = 157079.633

fy = 555.56

s = 150.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.75

Vf ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: Vs + Vf <= 457936.196

bw = 250.00

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,  $\phi = 0.86$

Mean strength values are used for both shear and moment calculations.

Consequently:

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

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

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with  $l_o/l_{o,min} = 0.30$

No FRP Wrapping

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = 0.33706551$

EDGE -B-

Shear Force,  $V_b = -0.33706551$

BOTH EDGES

Axial Force,  $F = -8883.863$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{sl,t} = 0.00$

-Compression:  $A_{sl,c} = 4121.77$

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,  $V_e/V_r = 0.71876765$

Member Controlled by Flexure ( $V_e/V_r < 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 358969.728$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 5.3845E+008$

$M_{u1+} = 5.3845E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.9011E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 5.3845E+008$

$M_{u2+} = 5.3845E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 2.9011E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of  $M_{u1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.2895006E-005$$

$$\mu = 5.3845E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00193327$$

$$N = 8883.863$$

$$f_c = 33.00$$

$$c_o(5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00616264$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.00616264$$

$$\phi_{ue} \text{ (5.4c)} = 0.00443103$$

$$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00321875$$

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)

$$\phi_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$\phi_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$su_1 = 0.4 * esu_1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_1_{nominal} = 0.08,$$

For calculation of  $esu_1_{nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 389.0139$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00140044$$

$sh_2 = 0.0044814$   
 $ft_2 = 466.8167$   
 $fy_2 = 389.0139$   
 $su_2 = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lo_{min} = lb/lb_{min} = 0.30$   
 $su_2 = 0.4 * esu_{2\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2\_nominal} = 0.08$ ,  
 For calculation of  $esu_{2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs_2 = fs = 389.0139$   
 with  $Es_2 = Es = 200000.00$   
 $yv = 0.00140044$   
 $shv = 0.0044814$   
 $ftv = 466.8167$   
 $fyv = 389.0139$   
 $suv = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lo_{min} = lb/ld = 0.30$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fsv = fs = 389.0139$   
 with  $Esv = Es = 200000.00$   
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.14787021$   
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.07021175$   
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.13084918$   
 and confined core properties:  
 $b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 33.00$   
 $cc (5A.5, TBDY) = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.20564193$   
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.09764293$   
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.18197092$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
 --->  
 $su (4.8) = 0.28715809$   
 $Mu = MRc (4.15) = 5.3845E+008$   
 $u = su (4.1) = 1.2895006E-005$

-----  
 Calculation of ratio  $lb/ld$   
 -----

Inadequate Lap Length with  $lb/ld = 0.30$   
 -----  
 -----  
 -----

Calculation of  $Mu_1$ -  
 -----  
 -----  
 -----

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.0873764E-005$$

$$\mu = 2.9011E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00080553$$

$$N = 8883.863$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00616264$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.00616264$$

$$\phi_{ue} \text{ (5.4c)} = 0.00443103$$

$$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00321875$$

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)

$$\phi_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$\phi_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 0.30$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{1,nominal} = 0.08,$$

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered

characteristic value  $fsy_1 = fs_1 / 1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 389.0139$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$su_2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lo_{u,min} = lb/lb_{u,min} = 0.30$$

$$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,

For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 389.0139$$

$$\text{with } Es_2 = Es = 200000.00$$

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lo_{u,min} = lb/ld = 0.30$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,

considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY

For calculation of  $esuv_{nominal}$  and  $yv, shv, ftv, fyv$ , it is considered characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 389.0139$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.0292549$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.06161259$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.05452049$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 33.00$$

$$cc (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.03435585$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.07235549$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.0640268$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs, y_2$  - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.15465327$$

$$Mu = MRc (4.14) = 2.9011E+008$$

$$u = su (4.1) = 1.0873764E-005$$

-----  
Calculation of ratio  $lb/ld$

-----  
Inadequate Lap Length with  $lb/ld = 0.30$   
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-----  
Calculation of  $Mu_{2+}$   
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-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.2895006E-005$$

$$Mu = 5.3845E+008$$

-----  
with full section properties:

b = 250.00

d = 557.00

d' = 43.00

v = 0.00193327

N = 8883.863

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.00616264

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.00616264

we (5.4c) = 0.00443103

ase = Max(((Aconf,max-AnoConf)/Aconf,max)\*(Aconf,min/Aconf,max),0) = 0.21805635

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 = 169100.00 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 = 98400.00 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 = 105733.333 is the unconfined core area which is equal to bi<sup>2</sup>/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00321875

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) = 0.00321875

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

-----  
psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

-----  
s = 150.00

fywe = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min = lb/d = 0.30

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/d)<sup>2/3</sup>), from 10.3.5, ASCE41-17.

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

$$su_2 = 0.4 * esu_{2\_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esu_{2\_nominal} = 0.08$ ,

For calculation of  $esu_{2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 389.0139$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$suv = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lo_{u,min} = lb/ld = 0.30$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,

considering characteristic value  $fsv = fsv/1.2$ , from table 5.1, TBDY

For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered characteristic value  $fsv = fsv/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 389.0139$$

$$\text{with } Es_v = Es = 200000.00$$

$$1 = Asl_{ten}/(b*d)*(fs_1/fc) = 0.14787021$$

$$2 = Asl_{com}/(b*d)*(fs_2/fc) = 0.07021175$$

$$v = Asl_{mid}/(b*d)*(fsv/fc) = 0.13084918$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 33.00$$

$$cc (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = Asl_{ten}/(b*d)*(fs_1/fc) = 0.20564193$$

$$2 = Asl_{com}/(b*d)*(fs_2/fc) = 0.09764293$$

$$v = Asl_{mid}/(b*d)*(fsv/fc) = 0.18197092$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$  - RHS eq.(4.5) is satisfied

--->

$$su (4.8) = 0.28715809$$

$$Mu = MRc (4.15) = 5.3845E+008$$

$$u = su (4.1) = 1.2895006E-005$$

-----  
Calculation of ratio  $lb/ld$

-----  
Inadequate Lap Length with  $lb/ld = 0.30$   
-----  
-----

-----  
Calculation of  $Mu_2$ -  
-----

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0873764E-005$$

$$Mu = 2.9011E+008$$

-----  
with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00080553$$

$$N = 8883.863$$

$$f_c = 33.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.00616264$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.00616264$$

$$w_e (5.4c) = 0.00443103$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along X}) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$su_1 = 0.4 * esu1_{nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_{nominal} = 0.08,$$

For calculation of  $esu1_{nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 389.0139$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$su_2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$$

$$su_2 = 0.4 * esu2_{nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_{nominal} = 0.08,$$

For calculation of  $esu2_{nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered

characteristic value  $f_{s2} = f_{s2}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $f_{s2} = f_s = 389.0139$

with  $E_{s2} = E_s = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$f_{y_v} = 389.0139$

$s_{u_v} = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/d = 0.30$

$s_{u_v} = 0.4 \cdot e_{s_{u_v,nominal}} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $e_{s_{u_v,nominal}} = 0.08$ ,

considering characteristic value  $f_{s_{y_v}} = f_{s_{y_v}}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{s_{u_v,nominal}}$  and  $y_v, sh_v, ft_v, f_{y_v}$ , it is considered  
characteristic value  $f_{s_{y_v}} = f_{s_{y_v}}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $f_{s_{y_v}} = f_s = 389.0139$

with  $E_{s_{y_v}} = E_s = 200000.00$

1 =  $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0292549$

2 =  $A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.06161259$

v =  $A_{s1,mid}/(b \cdot d) \cdot (f_{s_{y_v}}/f_c) = 0.05452049$

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

$f_{cc} (5A.2, TBDY) = 33.00$

$cc (5A.5, TBDY) = 0.002$

c = confinement factor = 1.00

1 =  $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03435585$

2 =  $A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.07235549$

v =  $A_{s1,mid}/(b \cdot d) \cdot (f_{s_{y_v}}/f_c) = 0.0640268$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$s_u (4.9) = 0.15465327$

$\mu_u = M_{Rc} (4.14) = 2.9011E+008$

u =  $s_u (4.1) = 1.0873764E-005$

-----  
Calculation of ratio  $l_b/d$

-----  
Inadequate Lap Length with  $l_b/d = 0.30$   
-----  
-----  
-----

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 499423.877$   
-----

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 515022.351$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} \cdot V_{Col0}$

$V_{Col0} = 515022.351$

$k_{nl} = 1$  (zero step-static loading)

-----  
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)

$f_c' = 33.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/d = 2.90582$

$\mu_u = 470.1368$

$V_u = 0.33706551$

d =  $0.8 \cdot h = 480.00$

$Nu = 8883.863$   
 $Ag = 150000.00$   
 From (11.5.4.8), ACI 318-14:  $Vs = Vs1 + Vs2 = 395611.129$   
 where:  
 $Vs1 = 116356.214$  is calculated for section web, with:  
 $d = 200.00$   
 $Av = 157079.633$   
 $fy = 555.56$   
 $s = 150.00$   
 $Vs1$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.75$   
 $Vs2 = 279254.914$  is calculated for section flange, with:  
 $d = 480.00$   
 $Av = 157079.633$   
 $fy = 555.56$   
 $s = 150.00$   
 $Vs2$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.3125$   
 $Vf ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $Vs + Vf \leq 457936.196$   
 $bw = 250.00$

Calculation of Shear Strength at edge 2,  $Vr2 = 499423.877$   
 $Vr2 = VCol ((10.3), ASCE 41-17) = knl * VColO$   
 $VColO = 499423.877$   
 $knl = 1$  (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)  
 $fc' = 33.00$ , but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 3.34244$   
 $Mu = 540.7776$   
 $Vu = 0.33706551$   
 $d = 0.8 * h = 480.00$   
 $Nu = 8883.863$   
 $Ag = 150000.00$   
 From (11.5.4.8), ACI 318-14:  $Vs = Vs1 + Vs2 = 395611.129$   
 where:  
 $Vs1 = 116356.214$  is calculated for section web, with:  
 $d = 200.00$   
 $Av = 157079.633$   
 $fy = 555.56$   
 $s = 150.00$   
 $Vs1$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.75$   
 $Vs2 = 279254.914$  is calculated for section flange, with:  
 $d = 480.00$   
 $Av = 157079.633$   
 $fy = 555.56$   
 $s = 150.00$   
 $Vs2$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.3125$   
 $Vf ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $Vs + Vf \leq 457936.196$   
 $bw = 250.00$

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: rclcs

#### Constant Properties

-----  
Knowledge Factor,  $\phi = 0.86$   
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.  
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Max Height,  $H_{max} = 600.00$   
Min Height,  $H_{min} = 250.00$   
Max Width,  $W_{max} = 600.00$   
Min Width,  $W_{min} = 250.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
No FRP Wrapping  
-----

#### Stepwise Properties

-----  
Bending Moment,  $M = -744250.973$   
Shear Force,  $V_2 = -5326.433$   
Shear Force,  $V_3 = 341.7795$   
Axial Force,  $F = -9995.934$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 4121.77$   
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,  $DbL = 17.71429$   
-----  
-----

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0^*$   $u = 0.02555275$   
 $u = y + p = 0.02555275$

-----  
- Calculation of  $y$  -  
-----

$y = (M_y * L_s / 3) / E_{eff} = 0.00449022$  ((4.29), Biskinis Phd))  
 $M_y = 3.3311E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 2177.576  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 5.3849E+013$   
factor = 0.30  
 $A_g = 237500.00$   
 $f_c' = 33.00$   
 $N = 9995.934$   
 $E_c * I_g = 1.7950E+014$   
-----  
-----

Calculation of Yielding Moment  $M_y$   
-----

Calculation of  $y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$   
 $y_{\text{ten}} = 4.3412800\text{E-}006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 311.2112$   
 $d = 557.00$   
 $y = 0.35649464$   
 $A = 0.02983044$   
 $B = 0.01921269$   
with  $pt = 0.01254381$   
 $pc = 0.00595605$   
 $pv = 0.01109992$   
 $N = 9995.934$   
 $b = 250.00$   
 $\rho = 0.07719928$   
 $y_{\text{comp}} = 1.1115910\text{E-}005$   
with  $f_c = 33.00$   
 $E_c = 26999.444$   
 $y = 0.3553296$   
 $A = 0.02943664$   
 $B = 0.01898202$   
with  $E_s = 200000.00$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

- Calculation of  $\rho_p$  -

From table 10-8:  $\rho_p = 0.02106253$

with:

- Columns not controlled by inadequate development or splicing along the clear height because  $l_b/d \geq 1$

shear control ratio  $V_y E / V_{CoI} E = 0.71876853$

$d = 557.00$

$s = 0.00$

$t = A_v / (b_w \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = A_v \cdot L_{stir} / (A_g \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$ , is the area of every stirrup

$L_{stir} = 1460.00$ , 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.

$N_{UD} = 9995.934$

$A_g = 237500.00$

$f_c E = 33.00$

$f_{yt} E = f_{yl} E = 0.00$

$\rho_l = \text{Area}_{\text{Tot\_Long\_Rein}} / (b \cdot d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_c E = 33.00$

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

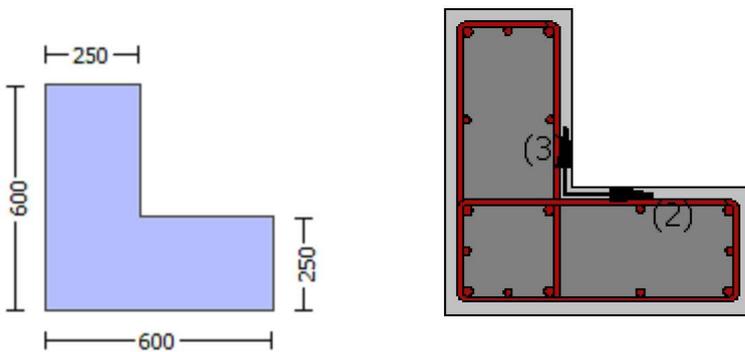
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

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: rdcs

Constant Properties

Knowledge Factor,  $\gamma = 0.86$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of  $\gamma$  for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

New material: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material: Steel Strength,  $f_s = f_{sm} = 555.56$

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_o/l_{ou,min} = l_b/d = 0.30$   
No FRP Wrapping

-----  
Stepwise Properties

-----  
EDGE -A-  
Bending Moment,  $M_a = -744250.973$   
Shear Force,  $V_a = 341.7795$   
EDGE -B-  
Bending Moment,  $M_b = -279938.259$   
Shear Force,  $V_b = -341.7795$   
BOTH EDGES  
Axial Force,  $F = -9995.934$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 4121.77$   
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,  $D_{bL,ten} = 17.71429$   
-----

-----  
New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 431774.345$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{CoI0} = 431774.345$   
 $V_{CoI} = 431774.345$   
 $k_n = 1.00$   
 $displacement\_ductility\_demand = 0.00655094$   
-----

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)  
 $f_c' = 25.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $M_u = 744250.973$   
 $V_u = 341.7795$   
 $d = 0.8 \cdot h = 480.00$   
 $N_u = 9995.934$   
 $A_g = 150000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 356047.167$   
where:  
 $V_{s1} = 251327.412$  is calculated for section web, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.3125$   
 $V_{s2} = 104719.755$  is calculated for section flange, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.75$   
 $V_f$  ((11-3)-(11.4), ACI 440) =  $0.00$   
From (11-11), ACI 440:  $V_s + V_f \leq 398582.298$   
 $bw = 250.00$   
-----

-----  
 $displacement\_ductility\_demand$  is calculated as / y  
-----

- Calculation of  $\phi_y$  for END A -  
for rotation axis 2 and integ. section (a)

-----  
From analysis, chord rotation  $\theta = 2.9415174E-005$   
 $y = (M_y \cdot L_s / 3) / E I_{eff} = 0.00449022$  ((4.29), Biskinis Phd))  
 $M_y = 3.3311E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 2177.576  
From table 10.5, ASCE 41\_17:  $E I_{eff} = \text{factor} \cdot E_c \cdot I_g = 5.3849E+013$   
factor = 0.30  
Ag = 237500.00  
fc' = 33.00  
N = 9995.934  
 $E_c \cdot I_g = 1.7950E+014$   
-----  
-----

Calculation of Yielding Moment  $M_y$

Calculation of  $\phi_y$  and  $M_y$  according to Annex 7 -

-----  
 $y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 4.3412800E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 311.2112$   
d = 557.00  
y = 0.35649464  
A = 0.02983044  
B = 0.01921269  
with pt = 0.01254381  
pc = 0.00595605  
pv = 0.01109992  
N = 9995.934  
b = 250.00  
" = 0.07719928  
 $y_{comp} = 1.1115910E-005$   
with fc = 33.00  
Ec = 26999.444  
y = 0.3553296  
A = 0.02943664  
B = 0.01898202  
with Es = 200000.00  
-----  
-----

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

-----  
End Of Calculation of Shear Capacity for element: column LC1 of floor 1  
At local axis: 3  
Integration Section: (a)  
-----

**Calculation No. 12**

column C1, Floor 1

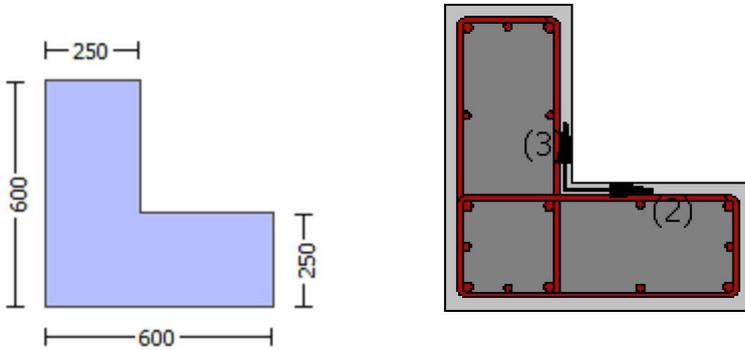
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\theta_u$ )

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,  $\gamma = 0.86$

Mean strength values are used for both shear and moment calculations.

Consequently:

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

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

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with  $l_o/l_{ou,min} = 0.30$

No FRP Wrapping

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 0.33706551$   
EDGE -B-  
Shear Force,  $V_b = -0.33706551$   
BOTH EDGES  
Axial Force,  $F = -8883.863$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{sl,t} = 0.00$   
-Compression:  $A_{sl,c} = 4121.77$   
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,  $V_e/V_r = 0.71876853$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 358969.728$   
with  
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 5.3845E+008$   
 $Mu_{1+} = 5.3845E+008$ , 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  
 $Mu_{1-} = 2.9011E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 5.3845E+008$   
 $Mu_{2+} = 5.3845E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination  
 $Mu_{2-} = 2.9011E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

-----  
Calculation of  $Mu_{1+}$   
-----

-----  
Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\phi_u = 1.2895006E-005$   
 $M_u = 5.3845E+008$

-----  
with full section properties:

$b = 250.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00193327$   
 $N = 8883.863$   
 $f_c = 33.00$   
 $\alpha_1 = 0.85$   
Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00616264$   
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY:  $\phi_u = 0.00616264$   
 $\phi_w$  (5.4c) = 0.00443103  
 $\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$   
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.  
 $A_{conf,max} = 169100.00$  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.  
 $A_{conf,min} = 98400.00$  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.  
 $A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $\phi_{psh,min} = \text{Min}(\phi_{psh,x}, \phi_{psh,y}) = 0.00321875$   
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)

psh,x ((5.4d), TBDY) =  $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) =  $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 150.00

fywe = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.30

su1 =  $0.4 \cdot esu1\_nominal$  ((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  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 =  $0.4 \cdot esu2\_nominal$  ((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  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.30

suv =  $0.4 \cdot esuv\_nominal$  ((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  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 =  $Asl,ten / (b \cdot d) \cdot (fs1 / fc) = 0.14787021$

2 =  $Asl,com / (b \cdot d) \cdot (fs2 / fc) = 0.07021175$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.13084918$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.20564193$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09764293$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.18197092$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$  - RHS eq.(4.5) is satisfied

--->

$$s_u (4.8) = 0.28715809$$

$$\mu_u = M R_c (4.15) = 5.3845E+008$$

$$u = s_u (4.1) = 1.2895006E-005$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{u1}$ -

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0873764E-005$$

$$\mu_u = 2.9011E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00080553$$

$$N = 8883.863$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.00616264$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.00616264$$

$$w_e (5.4c) = 0.00443103$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along } Y) = 1460.00$$

Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875  
Lstir (Length of stirrups along X) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

s = 150.00  
fywe = 694.45  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.002  
c = confinement factor = 1.00

y1 = 0.00140044  
sh1 = 0.0044814  
ft1 = 466.8167  
fy1 = 389.0139  
su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.30

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044  
sh2 = 0.0044814  
ft2 = 466.8167  
fy2 = 389.0139  
su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/b,min = 0.30

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044  
shv = 0.0044814  
ftv = 466.8167  
fyv = 389.0139  
suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.30

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY  
For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0292549

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.06161259

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.05452049

and confined core properties:

b = 540.00

$d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 33.00$   
 $cc (5A.5, TBDY) = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03435585$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07235549$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0640268$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.15465327$   
 $Mu = MRc (4.14) = 2.9011E+008$   
 $u = su (4.1) = 1.0873764E-005$

-----  
 Calculation of ratio  $l_b/l_d$

-----  
 Inadequate Lap Length with  $l_b/l_d = 0.30$   
 -----  
 -----

-----  
 Calculation of  $Mu_{2+}$   
 -----  
 -----

-----  
 Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 1.2895006E-005$   
 $Mu = 5.3845E+008$   
 -----

with full section properties:

$b = 250.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00193327$   
 $N = 8883.863$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00616264$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.00616264$   
 $w_e (5.4c) = 0.00443103$

$ase = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$   
 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.  
 $A_{conf,max} = 169100.00$  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.  
 $A_{conf,min} = 98400.00$  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.  
 $A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$   
 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)

-----  
 $p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$   
 $L_{stir}$  (Length of stirrups along Y) = 1460.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 237500.00  
 -----

$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$   
 $L_{stir}$  (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

s = 150.00

fywe = 694.45

fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb = 0.30

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb = 0.30

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.14787021

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.07021175

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.13084918

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 33.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.20564193$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09764293$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.18197092$$

Case/Assumption: Unconfined full section - Steel rupture  
 satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied

--->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied

--->  
 $\mu_u$  (4.8) = 0.28715809  
 $M_u = M_{Rc}$  (4.15) = 5.3845E+008  
 $u = \mu_u$  (4.1) = 1.2895006E-005

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{u2}$

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0873764E-005$$

$$M_u = 2.9011E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00080553$$

$$N = 8883.863$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

Final value of  $\mu_{cu}$ :  $\mu_{cu}^* = \text{shear\_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.00616264$   
 The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_{cu} = 0.00616264$   
 $\mu_{we}$  (5.4c) = 0.00443103

$$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.00321875$$

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)

$$\mu_{psh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$\mu_{psh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$s = 150.00$   
 $fy_{we} = 694.45$   
 $f_{ce} = 33.00$   
 From ((5.A.5), TBDY), TBDY:  $cc = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $y_1 = 0.00140044$   
 $sh_1 = 0.0044814$   
 $ft_1 = 466.8167$   
 $fy_1 = 389.0139$   
 $su_1 = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/ld = 0.30$   
 $su_1 = 0.4 * esu_{1\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{1\_nominal} = 0.08$ ,  
 For calculation of  $esu_{1\_nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
 characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs_1 = fs = 389.0139$   
 with  $Es_1 = Es = 200000.00$   
 $y_2 = 0.00140044$   
 $sh_2 = 0.0044814$   
 $ft_2 = 466.8167$   
 $fy_2 = 389.0139$   
 $su_2 = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/lb, \min = 0.30$   
 $su_2 = 0.4 * esu_{2\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2\_nominal} = 0.08$ ,  
 For calculation of  $esu_{2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs_2 = fs = 389.0139$   
 with  $Es_2 = Es = 200000.00$   
 $y_v = 0.00140044$   
 $sh_v = 0.0044814$   
 $ft_v = 466.8167$   
 $fy_v = 389.0139$   
 $suv = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/ld = 0.30$   
 $suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fsv = fs = 389.0139$   
 with  $Esv = Es = 200000.00$   
 $1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.0292549$   
 $2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.06161259$   
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.05452049$   
 and confined core properties:  
 $b = 540.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 33.00$   
 $cc (5A.5, TBDY) = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.03435585$   
 $2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.07235549$   
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.0640268$

Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->  
 $\mu$  (4.9) = 0.15465327  
 $\mu$  = MRc (4.14) = 2.9011E+008  
 $u$  =  $\mu$  (4.1) = 1.0873764E-005

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 499423.271$

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 515023.161$   
 $V_{r1} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} * V_{Col0}$   
 $V_{Col0} = 515023.161$   
 $k_{nl} = 1$  (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).

-----  
 $\lambda = 1$  (normal-weight concrete)  
 $f_c' = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.9058$   
 $\mu = 470.1336$   
 $V_u = 0.33706551$   
 $d = 0.8 * h = 480.00$   
 $N_u = 8883.863$   
 $A_g = 150000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$   
where:  
 $V_{s1} = 279254.914$  is calculated for section web, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.3125$   
 $V_{s2} = 116356.214$  is calculated for section flange, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.75$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440:  $V_s + V_f \leq 457936.196$   
 $b_w = 250.00$

-----  
Calculation of Shear Strength at edge 2,  $V_{r2} = 499423.271$

$V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} * V_{Col0}$   
 $V_{Col0} = 499423.271$   
 $k_{nl} = 1$  (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).

-----  
 $\lambda = 1$  (normal-weight concrete)  
 $f_c' = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 3.34246$

$\mu_u = 540.7808$   
 $V_u = 0.33706551$   
 $d = 0.8 \cdot h = 480.00$   
 $N_u = 8883.863$   
 $A_g = 150000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$   
 where:  
 $V_{s1} = 279254.914$  is calculated for section web, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.3125$   
 $V_{s2} = 116356.214$  is calculated for section flange, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.75$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 457936.196$   
 $b_w = 250.00$

-----  
 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,  $\phi = 0.86$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 #####  
 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  
 New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
 #####  
 Max Height,  $H_{max} = 600.00$   
 Min Height,  $H_{min} = 250.00$   
 Max Width,  $W_{max} = 600.00$   
 Min Width,  $W_{min} = 250.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.00  
 Element Length,  $L = 3000.00$   
 Primary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Inadequate Lap Length with  $l_o/l_{o,u,min} = 0.30$   
 No FRP Wrapping

## Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = 0.33706551$

EDGE -B-

Shear Force,  $V_b = -0.33706551$

BOTH EDGES

Axial Force,  $F = -8883.863$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 4121.77$

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,  $V_e/V_r = 0.71876765$

Member Controlled by Flexure ( $V_e/V_r < 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 358969.728$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 5.3845E+008$

$Mu_{1+} = 5.3845E+008$ , 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

$Mu_{1-} = 2.9011E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 5.3845E+008$

$Mu_{2+} = 5.3845E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$Mu_{2-} = 2.9011E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of  $Mu_{1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.2895006E-005$

$M_u = 5.3845E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00193327$

$N = 8883.863$

$f_c = 33.00$

$\alpha_c$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00616264$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.00616264$

$w_e$  (5.4c) = 0.00443103

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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 = 105733.333 is the unconfined core area which is equal to  $b^2/6$  as defined at (A.2).

$psh,min = \text{Min}(psh,x, psh,y) = 0.00321875$

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)

-----  
 $psh,x \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00321875$

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

-----  
 $psh,y \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00321875$

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

-----  
 $s = 150.00$

$fywe = 694.45$

$fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.002$

$c = \text{confinement factor} = 1.00$

$y1 = 0.00140044$

$sh1 = 0.0044814$

$ft1 = 466.8167$

$fy1 = 389.0139$

$su1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$lo/lou,min = lb/ld = 0.30$

$su1 = 0.4 * esu1\_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
characteristic value  $fsy1 = fs/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs1 = fs = 389.0139$

with  $Es1 = Es = 200000.00$

$y2 = 0.00140044$

$sh2 = 0.0044814$

$ft2 = 466.8167$

$fy2 = 389.0139$

$su2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$lo/lou,min = lb/lb,min = 0.30$

$su2 = 0.4 * esu2\_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
characteristic value  $fsy2 = fs/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs2 = fs = 389.0139$

with  $Es2 = Es = 200000.00$

$yv = 0.00140044$

$shv = 0.0044814$

$ftv = 466.8167$

$fyv = 389.0139$

$suv = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$lo/lou,min = lb/ld = 0.30$

$suv = 0.4 * esuv\_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,

considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered

characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 389.0139  
with Esv = Es = 200000.00  
1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.14787021  
2 = Asl,com/(b\*d)\*(fs2/fc) = 0.07021175  
v = Asl,mid/(b\*d)\*(fsv/fc) = 0.13084918

and confined core properties:

b = 190.00  
d = 527.00  
d' = 13.00  
fcc (5A.2, TBDY) = 33.00  
cc (5A.5, TBDY) = 0.002  
c = confinement factor = 1.00  
1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.20564193  
2 = Asl,com/(b\*d)\*(fs2/fc) = 0.09764293  
v = Asl,mid/(b\*d)\*(fsv/fc) = 0.18197092

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is not satisfied

--->

v < vs,c - RHS eq.(4.5) is satisfied

--->

su (4.8) = 0.28715809

Mu = MRc (4.15) = 5.3845E+008

u = su (4.1) = 1.2895006E-005

-----  
Calculation of ratio lb/l<sub>d</sub>

-----  
Inadequate Lap Length with lb/l<sub>d</sub> = 0.30  
-----  
-----

-----  
Calculation of Mu1-  
-----  
-----

-----  
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.0873764E-005

Mu = 2.9011E+008  
-----

with full section properties:

b = 600.00  
d = 557.00  
d' = 43.00  
v = 0.00080553  
N = 8883.863  
fc = 33.00  
co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.00616264

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.00616264

we (5.4c) = 0.00443103

ase = Max(((Aconf,max-AnoConf)/Aconf,max)\*(Aconf,min/Aconf,max),0) = 0.21805635

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 = 169100.00 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 = 98400.00 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 = 105733.333 is the unconfined core area which is equal to bi<sup>2</sup>/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00321875

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)

$$\text{psh}_x \text{ ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00321875$$

$$\text{Lstir (Length of stirrups along Y)} = 1460.00$$

$$\text{Astir (stirrups area)} = 78.53982$$

$$\text{Asec (section area)} = 237500.00$$

$$\text{psh}_y \text{ ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00321875$$

$$\text{Lstir (Length of stirrups along X)} = 1460.00$$

$$\text{Astir (stirrups area)} = 78.53982$$

$$\text{Asec (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 389.0139$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$su_2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$$

$$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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, ASCE41-17.

$$\text{with } fs_2 = fs = 389.0139$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$suv = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$suv = 0.4 * esuv_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,

considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 389.0139$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.0292549$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.06161259$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.05452049$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03435585$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07235549$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0640268$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.15465327$$

$$M_u = M_{Rc} (4.14) = 2.9011E+008$$

$$u = s_u (4.1) = 1.0873764E-005$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $M_{u2+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.2895006E-005$$

$$M_u = 5.3845E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00193327$$

$$N = 8883.863$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.00616264$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.00616264$$

$$w_e (5.4c) = 0.00443103$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along } Y) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 150.00

fywe = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.30

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.30

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY  
For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.14787021

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.07021175

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.13084918

and confined core properties:

b = 190.00

d = 527.00

$d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 33.00$   
 $cc (5A.5, TBDY) = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.20564193$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09764293$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.18197092$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
 --->  
 $su (4.8) = 0.28715809$   
 $Mu = MRc (4.15) = 5.3845E+008$   
 $u = su (4.1) = 1.2895006E-005$

-----  
 Calculation of ratio  $l_b/l_d$

-----  
 Inadequate Lap Length with  $l_b/l_d = 0.30$   
 -----  
 -----

-----  
 Calculation of  $Mu_2$ -  
 -----  
 -----

-----  
 Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.0873764E-005$   
 $Mu = 2.9011E+008$

-----  
 with full section properties:

$b = 600.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00080553$   
 $N = 8883.863$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00616264$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.00616264$   
 $w_e (5.4c) = 0.00443103$

$ase = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

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)

-----  
 $p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00  
 -----

$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

Lstir (Length of stirrups along X) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

s = 150.00

fywe = 694.45

fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY  
For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0292549

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.06161259

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.05452049

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 33.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00  
1 =  $Asl,ten/(b*d)*(fs1/fc) = 0.03435585$   
2 =  $Asl,com/(b*d)*(fs2/fc) = 0.07235549$   
v =  $Asl,mid/(b*d)*(fsv/fc) = 0.0640268$

Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)

--->  
v <  $v_s,y2$  - LHS eq.(4.5) is satisfied

--->  
su (4.9) = 0.15465327  
Mu = MRc (4.14) = 2.9011E+008  
u = su (4.1) = 1.0873764E-005

-----  
Calculation of ratio lb/ld

-----  
Inadequate Lap Length with lb/ld = 0.30  
-----  
-----

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 499423.877$   
-----

Calculation of Shear Strength at edge 1,  $V_{r1} = 515022.351$   
 $V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = knl * V_{Co10}$   
 $V_{Co10} = 515022.351$   
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)  
 $fc' = 33.00$ , but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.90582$   
Mu = 470.1368  
Vu = 0.33706551  
d = 0.8\*h = 480.00  
Nu = 8883.863  
Ag = 150000.00  
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$   
where:  
 $V_{s1} = 116356.214$  is calculated for section web, with:  
d = 200.00  
Av = 157079.633  
fy = 555.56  
s = 150.00  
 $V_{s1}$  is multiplied by Col1 = 1.00  
s/d = 0.75  
 $V_{s2} = 279254.914$  is calculated for section flange, with:  
d = 480.00  
Av = 157079.633  
fy = 555.56  
s = 150.00  
 $V_{s2}$  is multiplied by Col2 = 1.00  
s/d = 0.3125  
Vf ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440:  $V_s + V_f \leq 457936.196$   
bw = 250.00  
-----

-----  
Calculation of Shear Strength at edge 2,  $V_{r2} = 499423.877$   
 $V_{r2} = V_{Co2} ((10.3), ASCE 41-17) = knl * V_{Co10}$   
 $V_{Co10} = 499423.877$   
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)  
 $f_c' = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 3.34244$   
 $\mu_u = 540.7776$   
 $V_u = 0.33706551$   
 $d = 0.8 \cdot h = 480.00$   
 $N_u = 8883.863$   
 $A_g = 150000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$   
where:  
 $V_{s1} = 116356.214$  is calculated for section web, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.75$   
 $V_{s2} = 279254.914$  is calculated for section flange, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.3125$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
From (11-11), ACI 440:  $V_s + V_f \leq 457936.196$   
 $b_w = 250.00$   
-----

-----  
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,  $\gamma = 0.86$   
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.  
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Max Height,  $H_{max} = 600.00$   
Min Height,  $H_{min} = 250.00$   
Max Width,  $W_{max} = 600.00$   
Min Width,  $W_{min} = 250.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
No FRP Wrapping  
-----

Stepwise Properties

Bending Moment,  $M = -1.6331E+007$   
Shear Force,  $V2 = -5326.433$   
Shear Force,  $V3 = 341.7795$   
Axial Force,  $F = -9995.934$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 4121.77$   
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,  $Db_L = 17.71429$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0^*$   $u = 0.02738458$   
 $u = y + p = 0.02738458$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00632205$  ((4.29), Biskinis Phd))  
 $M_y = 3.3311E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3065.941  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 5.3849E+013$   
 $factor = 0.30$   
 $A_g = 237500.00$   
 $fc' = 33.00$   
 $N = 9995.934$   
 $E_c * I_g = 1.7950E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{,ten}, y_{,com})$   
 $y_{,ten} = 4.3412800E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / d)^{2/3}) = 311.2112$   
 $d = 557.00$   
 $y = 0.35649464$   
 $A = 0.02983044$   
 $B = 0.01921269$   
with  $p_t = 0.01254381$   
 $p_c = 0.00595605$   
 $p_v = 0.01109992$   
 $N = 9995.934$   
 $b = 250.00$   
 $" = 0.07719928$   
 $y_{,comp} = 1.1115910E-005$   
with  $fc = 33.00$   
 $E_c = 26999.444$   
 $y = 0.3553296$   
 $A = 0.02943664$   
 $B = 0.01898202$   
with  $E_s = 200000.00$

Calculation of ratio  $l_b / d$

Inadequate Lap Length with  $l_b / d = 0.30$

- Calculation of  $\rho$  -

From table 10-8:  $\rho = 0.02106253$

with:

- Columns not controlled by inadequate development or splicing along the clear height because  $l_b/l_d \geq 1$   
shear control ratio  $V_{yE}/V_{CoIE} = 0.71876765$

$d = 557.00$

$s = 0.00$

$t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.00$

$A_v = 78.53982$ , is the area of every stirrup

$L_{stir} = 1460.00$ , 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.

$NUD = 9995.934$

$A_g = 237500.00$

$f_{cE} = 33.00$

$f_{ytE} = f_{ylE} = 0.00$

$\rho_l = \text{Area\_Tot\_Long\_Rein}/(b*d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_{cE} = 33.00$

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

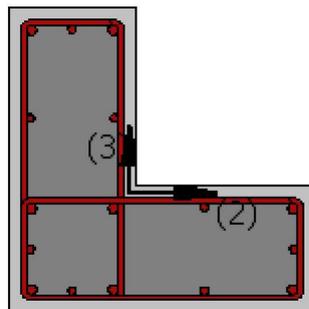
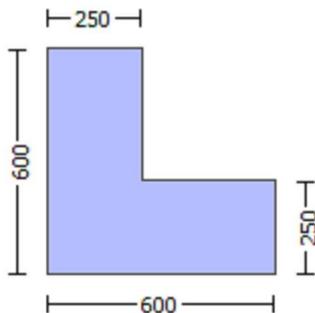
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rdcs

Constant Properties

Knowledge Factor,  $\gamma = 0.86$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of  $\gamma$  for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

New material: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material: Steel Strength,  $f_s = f_{sm} = 555.56$

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with  $l_o/l_{o,min} = l_b/l_d = 0.30$

No FRP Wrapping

Stepwise Properties

EDGE -A-

Bending Moment,  $M_a = -1.6331E+007$

Shear Force,  $V_a = -5326.433$

EDGE -B-

Bending Moment,  $M_b = 347029.948$

Shear Force,  $V_b = 5326.433$

BOTH EDGES

Axial Force,  $F = -9995.934$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $A_{sc} = 4121.77$

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,  $Db_{L,ten} = 17.71429$

New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 507501.522$

$V_n ((10.3), ASCE 41-17) = knl \cdot V_{CoI} = 507501.522$

$V_{CoI} = 507501.522$

$knl = 1.00$

$displacement\_ductility\_demand = 0.07739406$

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' = 25.00, but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
M/Vd = 2.00  
Mu = 347029.948  
Vu = 5326.433  
d = 0.8\*h = 480.00  
Nu = 9995.934  
Ag = 150000.00  
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 356047.167  
where:  
Vs1 = 104719.755 is calculated for section web, with:  
d = 200.00  
Av = 157079.633  
fy = 500.00  
s = 150.00  
Vs1 is multiplied by Col1 = 1.00  
s/d = 0.75  
Vs2 = 251327.412 is calculated for section flange, with:  
d = 480.00  
Av = 157079.633  
fy = 500.00  
s = 150.00  
Vs2 is multiplied by Col2 = 1.00  
s/d = 0.3125  
Vf ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440: Vs + Vf <= 398582.298  
bw = 250.00

displacement ductility demand is calculated as / y

- Calculation of / y for END B -  
for rotation axis 3 and integ. section (b)

From analysis, chord rotation = 4.7876570E-005  
y = (My\*Ls/3)/Eleff = 0.00061861 ((4.29),Biskinis Phd))  
My = 3.3311E+008  
Ls = M/V (with Ls > 0.1\*L and Ls < 2\*L) = 300.00  
From table 10.5, ASCE 41\_17: Eleff = factor\*Ec\*Ig = 5.3849E+013  
factor = 0.30  
Ag = 237500.00  
fc' = 33.00  
N = 9995.934  
Ec\*Ig = 1.7950E+014

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

y = Min( y\_ten, y\_com)  
y\_ten = 4.3412800E-006  
with ((10.1), ASCE 41-17) fy = Min(fy, 1.25\*fy\*(lb/d)^2/3) = 311.2112  
d = 557.00  
y = 0.35649464  
A = 0.02983044  
B = 0.01921269  
with pt = 0.01254381  
pc = 0.00595605  
pv = 0.01109992  
N = 9995.934  
b = 250.00

$$\nu = 0.07719928$$

$$y_{comp} = 1.1115910E-005$$

with  $f_c = 33.00$

$$E_c = 26999.444$$

$$y = 0.3553296$$

$$A = 0.02943664$$

$$B = 0.01898202$$

with  $E_s = 200000.00$

Calculation of ratio  $I_b/I_d$

Inadequate Lap Length with  $I_b/I_d = 0.30$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 14

column C1, Floor 1

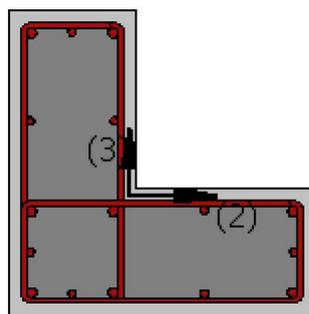
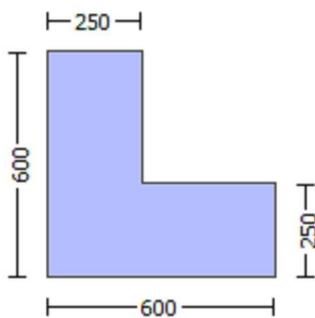
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\mu$ )

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rclcs

Constant Properties

Knowledge Factor,  $\nu = 0.86$

Mean strength values are used for both shear and moment calculations.

Consequently:

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

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

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with  $l_o/l_{ou,min} = 0.30$

No FRP Wrapping

-----  
Stepwise Properties

-----  
At local axis: 3

EDGE -A-

Shear Force,  $V_a = 0.33706551$

EDGE -B-

Shear Force,  $V_b = -0.33706551$

BOTH EDGES

Axial Force,  $F = -8883.863$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{sl,t} = 0.00$

-Compression:  $A_{sl,c} = 4121.77$

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,  $V_e/V_r = 0.71876853$

Member Controlled by Flexure ( $V_e/V_r < 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 358969.728$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 5.3845E+008$

$M_{u1+} = 5.3845E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.9011E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 5.3845E+008$

$M_{u2+} = 5.3845E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 2.9011E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

-----  
Calculation of  $M_{u1+}$

-----  
Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

u = 1.2895006E-005  
Mu = 5.3845E+008

with full section properties:

b = 250.00

d = 557.00

d' = 43.00

v = 0.00193327

N = 8883.863

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.00616264

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.00616264

we (5.4c) = 0.00443103

ase = Max(((Aconf,max-AnoConf)/Aconf,max)\*(Aconf,min/Aconf,max),0) = 0.21805635

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 = 169100.00 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 = 98400.00 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 = 105733.333 is the unconfined core area which is equal to bi<sup>2</sup>/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00321875

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) = 0.00321875

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 150.00

fywe = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min = lb/d = 0.30

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/d)<sup>2/3</sup>), from 10.3.5, ASCE41-17.

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$$

$$s_u2 = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{su2,nominal} = 0.08$ ,

For calculation of  $e_{su2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } f_{s2} = f_s = 389.0139$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$s_{uv} = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{suv,nominal} = 0.08$ ,

considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{suv,nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } f_{sv} = f_s = 389.0139$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.14787021$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.07021175$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.13084918$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.00$$

$$cc (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.20564193$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.09764293$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.18197092$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$  - RHS eq.(4.5) is satisfied

--->

$$s_u (4.8) = 0.28715809$$

$$M_u = M_{Rc} (4.15) = 5.3845E+008$$

$$u = s_u (4.1) = 1.2895006E-005$$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
-----  
-----  
-----

-----  
Calculation of  $M_{u1}$ -  
-----  
-----

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0873764E-005$$

$$M_u = 2.9011E+008$$
  
-----

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00080553$$

$$N = 8883.863$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.00616264$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.00616264$$

$$w_e \text{ (5.4c)} = 0.00443103$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o / l_{ou,min} = l_b / d = 0.30$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{1,nominal} = 0.08,$$

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1 / 1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b / d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 389.0139$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$su_2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$$

$$s_u2 = 0.4 * e_{s_u2\_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{s_u2\_nominal} = 0.08$ ,

For calculation of  $e_{s_u2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $f_{s_y2} = f_{s_2}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } f_{s_2} = f_s = 389.0139$$

$$\text{with } E_{s_2} = E_s = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$s_{u_v} = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$s_{u_v} = 0.4 * e_{s_{u_v}\_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{s_{u_v}\_nominal} = 0.08$ ,

considering characteristic value  $f_{s_{y_v}} = f_{s_v}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{s_{u_v}\_nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered characteristic value  $f_{s_{y_v}} = f_{s_v}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } f_{s_v} = f_s = 389.0139$$

$$\text{with } E_{s_v} = E_s = 200000.00$$

$$1 = A_{s_{l,ten}} / (b * d) * (f_{s_1} / f_c) = 0.0292549$$

$$2 = A_{s_{l,com}} / (b * d) * (f_{s_2} / f_c) = 0.06161259$$

$$v = A_{s_{l,mid}} / (b * d) * (f_{s_v} / f_c) = 0.05452049$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.00$$

$$cc (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = A_{s_{l,ten}} / (b * d) * (f_{s_1} / f_c) = 0.03435585$$

$$2 = A_{s_{l,com}} / (b * d) * (f_{s_2} / f_c) = 0.07235549$$

$$v = A_{s_{l,mid}} / (b * d) * (f_{s_v} / f_c) = 0.0640268$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.15465327$$

$$M_u = M_{Rc} (4.14) = 2.9011E+008$$

$$u = s_u (4.1) = 1.0873764E-005$$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
-----  
-----

-----  
Calculation of  $M_{u2+}$   
-----  
-----

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.2895006E-005$$

$$M_u = 5.3845E+008$$

-----  
with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00193327$$

$$N = 8883.863$$

$$f_c = 33.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.00616264$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.00616264$$

$$w_e (5.4c) = 0.00443103$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along X}) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$f_{t1} = 466.8167$$

$$f_{y1} = 389.0139$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 0.30$$

$$su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{1,nominal} = 0.08,$$

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, f_{t1}, f_{y1}$ , it is considered characteristic value  $fs_1 = fs_1 / 1.2$ , from table 5.1, TBDY.

$y_1, sh_1, f_{t1}, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 389.0139$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$f_{t2} = 466.8167$$

$$f_{y2} = 389.0139$$

$$su_2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_{b,min} = 0.30$$

$$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{2,nominal} = 0.08,$$

For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, f_{t2}, f_{y2}$ , it is considered characteristic value  $fs_2 = fs_2 / 1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_2 = fs = 389.0139$

with  $Es_2 = Es = 200000.00$

$yv = 0.00140044$

$shv = 0.0044814$

$ftv = 466.8167$

$fyv = 389.0139$

$suv = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lou, \min = lb/ld = 0.30$

$suv = 0.4 \cdot esuv_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY:  $esuv_{\text{nominal}} = 0.08$ ,

considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY

For calculation of  $esuv_{\text{nominal}}$  and  $yv, shv, ftv, fyv$ , it is considered

characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fsv = fs = 389.0139$

with  $Es_v = Es = 200000.00$

1 =  $Asl, \text{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.14787021$

2 =  $Asl, \text{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.07021175$

v =  $Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.13084918$

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 33.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 =  $Asl, \text{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.20564193$

2 =  $Asl, \text{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.09764293$

v =  $Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.18197092$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs, y_2$  - LHS eq.(4.5) is not satisfied

--->

$v < vs, c$  - RHS eq.(4.5) is satisfied

--->

$su$  (4.8) = 0.28715809

$Mu = MRc$  (4.15) = 5.3845E+008

u =  $su$  (4.1) = 1.2895006E-005

-----  
Calculation of ratio  $lb/ld$

-----  
Inadequate Lap Length with  $lb/ld = 0.30$   
-----  
-----

-----  
Calculation of  $Mu_2$ -  
-----  
-----

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

u = 1.0873764E-005

Mu = 2.9011E+008  
-----

with full section properties:

b = 600.00

d = 557.00

d' = 43.00

v = 0.00080553

N = 8883.863

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00616264$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $cu = 0.00616264$

we (5.4c) = 0.00443103

$ase = \text{Max}(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.21805635$

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 = 169100.00 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 = 98400.00 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 = 105733.333 is the unconfined core area which is equal to  $bi^2/6$  as defined at (A.2).

$psh,min = \text{Min}(psh,x, psh,y) = 0.00321875$

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) =  $Lstir * Astir / (Asec * s) = 0.00321875$

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

-----  
 $psh,y$  ((5.4d), TBDY) =  $Lstir * Astir / (Asec * s) = 0.00321875$

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

-----  
 $s = 150.00$

$fywe = 694.45$

$fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.002$

$c = \text{confinement factor} = 1.00$

$y1 = 0.00140044$

$sh1 = 0.0044814$

$ft1 = 466.8167$

$fy1 = 389.0139$

$su1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lou,min = lb/d = 0.30$

$su1 = 0.4 * esu1\_nominal$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs1 = fs = 389.0139$

with  $Es1 = Es = 200000.00$

$y2 = 0.00140044$

$sh2 = 0.0044814$

$ft2 = 466.8167$

$fy2 = 389.0139$

$su2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lou,min = lb/lb,min = 0.30$

$su2 = 0.4 * esu2\_nominal$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs2 = fs = 389.0139$

with  $Es2 = Es = 200000.00$

yv = 0.00140044  
shv = 0.0044814  
ftv = 466.8167  
fyv = 389.0139  
suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.30

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0292549

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.06161259

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.05452049

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 33.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.03435585

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.07235549

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.0640268

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---

v < vs,y2 - LHS eq.(4.5) is satisfied

---

su (4.9) = 0.15465327

Mu = MRc (4.14) = 2.9011E+008

u = su (4.1) = 1.0873764E-005

-----  
Calculation of ratio lb/d

-----  
Inadequate Lap Length with lb/d = 0.30  
-----  
-----  
-----

-----  
Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 499423.271  
-----

-----  
Calculation of Shear Strength at edge 1, Vr1 = 515023.161

Vr1 = VCol ((10.3), ASCE 41-17) = knl\*VCol0

VCol0 = 515023.161

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' = 33.00, but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.9058

Mu = 470.1336

Vu = 0.33706551

d = 0.8\*h = 480.00

Nu = 8883.863

Ag = 150000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 395611.129

where:

Vs1 = 279254.914 is calculated for section web, with:

d = 480.00

Av = 157079.633

fy = 555.56

s = 150.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.3125

Vs2 = 116356.214 is calculated for section flange, with:

d = 200.00

Av = 157079.633

fy = 555.56

s = 150.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.75

Vf ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: Vs + Vf <= 457936.196

bw = 250.00

Calculation of Shear Strength at edge 2, Vr2 = 499423.271

Vr2 = VCol ((10.3), ASCE 41-17) = knl\*VCol0

VCol0 = 499423.271

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' = 33.00, but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

M/Vd = 3.34246

Mu = 540.7808

Vu = 0.33706551

d = 0.8\*h = 480.00

Nu = 8883.863

Ag = 150000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 395611.129

where:

Vs1 = 279254.914 is calculated for section web, with:

d = 480.00

Av = 157079.633

fy = 555.56

s = 150.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.3125

Vs2 = 116356.214 is calculated for section flange, with:

d = 200.00

Av = 157079.633

fy = 555.56

s = 150.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.75

Vf ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: Vs + Vf <= 457936.196

bw = 250.00

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,  $\phi = 0.86$

Mean strength values are used for both shear and moment calculations.

Consequently:

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

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

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with  $l_o/l_{o,min} = 0.30$

No FRP Wrapping

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = 0.33706551$

EDGE -B-

Shear Force,  $V_b = -0.33706551$

BOTH EDGES

Axial Force,  $F = -8883.863$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{sl,t} = 0.00$

-Compression:  $A_{sl,c} = 4121.77$

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,  $V_e/V_r = 0.71876765$

Member Controlled by Flexure ( $V_e/V_r < 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 358969.728$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 5.3845E+008$

$M_{u1+} = 5.3845E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.9011E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 5.3845E+008$

$M_{u2+} = 5.3845E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 2.9011E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of  $M_{u1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.2895006E-005$$

$$\mu = 5.3845E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00193327$$

$$N = 8883.863$$

$$f_c = 33.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00616264$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.00616264$$

$$\phi_{ue}(5.4c) = 0.00443103$$

$$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00321875$$

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)

$$\phi_{sh,x}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$\phi_{sh,y}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.30$$

$$su_1 = 0.4 * esu_{1,nominal}((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{1,nominal} = 0.08,$$

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 389.0139$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00140044$$

$sh_2 = 0.0044814$   
 $ft_2 = 466.8167$   
 $fy_2 = 389.0139$   
 $su_2 = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lo_{u,min} = lb/lb_{u,min} = 0.30$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs_2 = fs = 389.0139$   
 with  $Es_2 = Es = 200000.00$   
 $yv = 0.00140044$   
 $shv = 0.0044814$   
 $ftv = 466.8167$   
 $fyv = 389.0139$   
 $suv = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lo_{u,min} = lb/ld = 0.30$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fsv = fs = 389.0139$   
 with  $Esv = Es = 200000.00$   
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.14787021$   
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.07021175$   
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.13084918$   
 and confined core properties:  
 $b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 33.00$   
 $cc (5A.5, TBDY) = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.20564193$   
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.09764293$   
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.18197092$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
 --->  
 $su (4.8) = 0.28715809$   
 $Mu = MRc (4.15) = 5.3845E+008$   
 $u = su (4.1) = 1.2895006E-005$

-----  
 Calculation of ratio  $lb/ld$

-----  
 Inadequate Lap Length with  $lb/ld = 0.30$   
 -----  
 -----

-----  
 Calculation of  $Mu_1$ -  
 -----  
 -----

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.0873764E-005$$

$$\mu_u = 2.9011E+008$$

-----  
with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00080553$$

$$N = 8883.863$$

$$f_c = 33.00$$

$$\omega (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00616264$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.00616264$$

$$\phi_{ue} (5.4c) = 0.00443103$$

$$\text{ase} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$$

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.

$A_{\text{conf,max}} = 169100.00$  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.

$A_{\text{conf,min}} = 98400.00$  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.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00321875$$

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)

$$\phi_{sh,x} ((5.4d), \text{TBDY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} (\text{Length of stirrups along Y}) = 1460.00$$

$$A_{\text{stir}} (\text{stirrups area}) = 78.53982$$

$$A_{\text{sec}} (\text{section area}) = 237500.00$$

$$\phi_{sh,y} ((5.4d), \text{TBDY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} (\text{Length of stirrups along X}) = 1460.00$$

$$A_{\text{stir}} (\text{stirrups area}) = 78.53982$$

$$A_{\text{sec}} (\text{section area}) = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A.5), TBDY), TBDY: } \phi_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

$$\text{Shear\_factor} = 1.00$$

$$l_o / l_{ou,min} = l_b / l_d = 0.30$$

$$su_1 = 0.4 * esu_{1,nominal} ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{1,nominal} = 0.08,$$

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, ASCE41-17.

$$\text{with } fs_1 = fs = 389.0139$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$su_2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$$

$$su_2 = 0.4 * esu_2_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esu_2_{nominal} = 0.08$ ,

For calculation of  $esu_2_{nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 389.0139$$

$$\text{with } Es_2 = Es = 200000.00$$

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,

considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY

For calculation of  $esuv_{nominal}$  and  $yv, shv, ftv, fyv$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 389.0139$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.0292549$$

$$2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.06161259$$

$$v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.05452049$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 33.00$$

$$cc (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.03435585$$

$$2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.07235549$$

$$v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.0640268$$

Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.15465327$$

$$Mu = MRc (4.14) = 2.9011E+008$$

$$u = su (4.1) = 1.0873764E-005$$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$

-----  
Calculation of  $Mu_{2+}$

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.2895006E-005$$

$$Mu = 5.3845E+008$$

-----  
with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00193327$$

$$N = 8883.863$$

$$f_c = 33.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.00616264$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.00616264$$

$$w_e (5.4c) = 0.00443103$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along X}) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o / l_{ou,min} = l_b / d = 0.30$$

$$su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{1,nominal} = 0.08,$$

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1 / 1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b / d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 389.0139$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$su_2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_{b,min} = 0.30$$

$$su_2 = 0.4 * esu_{2\_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esu_{2\_nominal} = 0.08$ ,

For calculation of  $esu_{2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 389.0139$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$suv = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lo_{u,min} = lb/ld = 0.30$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,

considering characteristic value  $fsv = fsv/1.2$ , from table 5.1, TBDY

For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered characteristic value  $fsv = fsv/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 389.0139$$

$$\text{with } Es_v = Es = 200000.00$$

$$1 = Asl_{ten}/(b*d)*(fs_1/fc) = 0.14787021$$

$$2 = Asl_{com}/(b*d)*(fs_2/fc) = 0.07021175$$

$$v = Asl_{mid}/(b*d)*(fsv/fc) = 0.13084918$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 33.00$$

$$cc (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = Asl_{ten}/(b*d)*(fs_1/fc) = 0.20564193$$

$$2 = Asl_{com}/(b*d)*(fs_2/fc) = 0.09764293$$

$$v = Asl_{mid}/(b*d)*(fsv/fc) = 0.18197092$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$  - RHS eq.(4.5) is satisfied

--->

$$su (4.8) = 0.28715809$$

$$Mu = MRc (4.15) = 5.3845E+008$$

$$u = su (4.1) = 1.2895006E-005$$

-----  
Calculation of ratio  $lb/ld$

-----  
Inadequate Lap Length with  $lb/ld = 0.30$   
-----  
-----

-----  
Calculation of  $Mu_2$ -  
-----

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0873764E-005$$

$$Mu = 2.9011E+008$$

-----  
with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00080553$$

$$N = 8883.863$$

$$f_c = 33.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.00616264$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.00616264$$

$$w_e (5.4c) = 0.00443103$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along X}) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{1,nominal} = 0.08,$$

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 389.0139$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$su_2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$$

$$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{2,nominal} = 0.08,$$

For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered

characteristic value  $f_{s2} = f_{s2}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $f_{s2} = f_s = 389.0139$

with  $E_{s2} = E_s = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$f_{yv} = 389.0139$

$s_{uv} = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30$

$s_{uv} = 0.4 \cdot e_{suv,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $e_{suv,nominal} = 0.08$ ,

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{suv,nominal}$  and  $y_v, sh_v, ft_v, f_{yv}$ , 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, ASCE41-17.

with  $f_{sv} = f_s = 389.0139$

with  $E_{sv} = E_s = 200000.00$

1 =  $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0292549$

2 =  $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.06161259$

v =  $A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.05452049$

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

f<sub>cc</sub> (5A.2, TBDY) = 33.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 =  $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03435585$

2 =  $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.07235549$

v =  $A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.0640268$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---

v < v<sub>s,y2</sub> - LHS eq.(4.5) is satisfied

---

su (4.9) = 0.15465327

Mu = MRc (4.14) = 2.9011E+008

u = su (4.1) = 1.0873764E-005

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
-----  
-----  
-----

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 499423.877$   
-----

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 515022.351$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} \cdot V_{Col0}$

$V_{Col0} = 515022.351$

$k_{nl} = 1$  (zero step-static loading)

-----  
NOTE: In expression (10-3) 'V<sub>s</sub>' is replaced by 'V<sub>s</sub> + f\*V<sub>f</sub>'

where V<sub>f</sub> is the contribution of FRPs (11.3), ACI 440).

-----  
= 1 (normal-weight concrete)

f<sub>c</sub>' = 33.00, but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.90582

Mu = 470.1368

Vu = 0.33706551

d = 0.8\*h = 480.00

Nu = 8883.863  
Ag = 150000.00  
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$   
where:  
Vs1 = 116356.214 is calculated for section web, with:  
d = 200.00  
Av = 157079.633  
fy = 555.56  
s = 150.00  
Vs1 is multiplied by Col1 = 1.00  
s/d = 0.75  
Vs2 = 279254.914 is calculated for section flange, with:  
d = 480.00  
Av = 157079.633  
fy = 555.56  
s = 150.00  
Vs2 is multiplied by Col2 = 1.00  
s/d = 0.3125  
Vf ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440:  $V_s + V_f \leq 457936.196$   
bw = 250.00

-----  
Calculation of Shear Strength at edge 2, Vr2 = 499423.877  
Vr2 = VCol ((10.3), ASCE 41-17) = knl\*VCol0  
VCol0 = 499423.877  
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' = 33.00, but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
M/Vd = 3.34244  
Mu = 540.7776  
Vu = 0.33706551  
d = 0.8\*h = 480.00  
Nu = 8883.863  
Ag = 150000.00  
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$   
where:  
Vs1 = 116356.214 is calculated for section web, with:  
d = 200.00  
Av = 157079.633  
fy = 555.56  
s = 150.00  
Vs1 is multiplied by Col1 = 1.00  
s/d = 0.75  
Vs2 = 279254.914 is calculated for section flange, with:  
d = 480.00  
Av = 157079.633  
fy = 555.56  
s = 150.00  
Vs2 is multiplied by Col2 = 1.00  
s/d = 0.3125  
Vf ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440:  $V_s + V_f \leq 457936.196$   
bw = 250.00

-----  
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,  $\phi = 0.86$   
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.  
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Max Height,  $H_{max} = 600.00$   
Min Height,  $H_{min} = 250.00$   
Max Width,  $W_{max} = 600.00$   
Min Width,  $W_{min} = 250.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
No FRP Wrapping

#### Stepwise Properties

-----  
Bending Moment,  $M = -279938.259$   
Shear Force,  $V_2 = 5326.433$   
Shear Force,  $V_3 = -341.7795$   
Axial Force,  $F = -9995.934$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 4121.77$   
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,  $DbL = 17.71429$

-----  
New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0^*$   $u = 0.02275145$   
 $u = y + p = 0.02275145$

-----  
- Calculation of  $y$  -

-----  
 $y = (M_y * L_s / 3) / E_{eff} = 0.00168892$  ((4.29), Biskinis Phd))  
 $M_y = 3.3311E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 819.0609  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 5.3849E+013$   
factor = 0.30  
 $A_g = 237500.00$   
 $f_c' = 33.00$   
 $N = 9995.934$   
 $E_c * I_g = 1.7950E+014$

-----  
Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$   
 $y_{\text{ten}} = 4.3412800\text{E-}006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25*f_y*(l_b/l_d)^{2/3}) = 311.2112$   
 $d = 557.00$   
 $y = 0.35649464$   
 $A = 0.02983044$   
 $B = 0.01921269$   
with  $pt = 0.01254381$   
 $pc = 0.00595605$   
 $pv = 0.01109992$   
 $N = 9995.934$   
 $b = 250.00$   
 $\rho = 0.07719928$   
 $y_{\text{comp}} = 1.1115910\text{E-}005$   
with  $f_c = 33.00$   
 $E_c = 26999.444$   
 $y = 0.3553296$   
 $A = 0.02943664$   
 $B = 0.01898202$   
with  $E_s = 200000.00$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

- Calculation of  $p$  -

From table 10-8:  $p = 0.02106253$

with:

- Columns not controlled by inadequate development or splicing along the clear height because  $l_b/l_d >= 1$

shear control ratio  $V_y E / V_{CoI} E = 0.71876853$

$d = 557.00$

$s = 0.00$

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$ , is the area of every stirrup

$L_{stir} = 1460.00$ , 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.

$N_{UD} = 9995.934$

$A_g = 237500.00$

$f_{cE} = 33.00$

$f_{ytE} = f_{ylE} = 0.00$

$p_l = \text{Area}_{\text{Tot\_Long\_Rein}} / (b * d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_{cE} = 33.00$

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

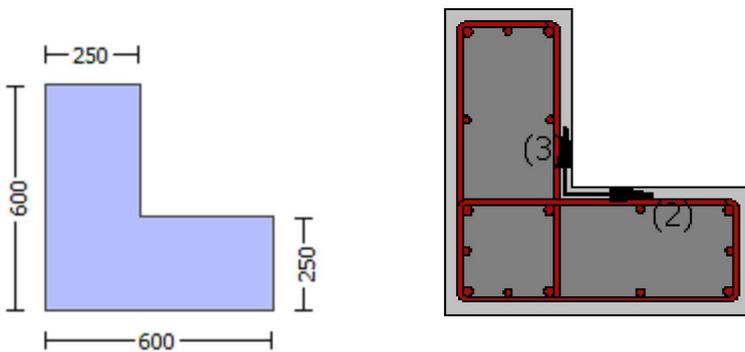
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

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,  $\gamma = 0.86$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of  $\gamma$  for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

New material: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material: Steel Strength,  $f_s = f_{sm} = 555.56$

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_o/l_{ou,min} = l_b/d = 0.30$   
No FRP Wrapping

-----  
Stepwise Properties

-----  
EDGE -A-  
Bending Moment,  $M_a = -744250.973$   
Shear Force,  $V_a = 341.7795$   
EDGE -B-  
Bending Moment,  $M_b = -279938.259$   
Shear Force,  $V_b = -341.7795$   
BOTH EDGES  
Axial Force,  $F = -9995.934$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 4121.77$   
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,  $D_{bL,ten} = 17.71429$

-----  
New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 507501.522$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{CoI0} = 507501.522$   
 $V_{CoI} = 507501.522$   
 $k_n = 1.00$   
 $displacement\_ductility\_demand = 9.8337420E-006$

-----  
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)  
 $f_c' = 25.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $M_u = 279938.259$   
 $V_u = 341.7795$   
 $d = 0.8 \cdot h = 480.00$   
 $N_u = 9995.934$   
 $A_g = 150000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 356047.167$   
where:  
 $V_{s1} = 251327.412$  is calculated for section web, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.3125$   
 $V_{s2} = 104719.755$  is calculated for section flange, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.75$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440:  $V_s + V_f \leq 398582.298$   
 $b_w = 250.00$

-----  
 $displacement\_ductility\_demand$  is calculated as / y

- Calculation of  $\phi_y$  for END B -  
for rotation axis 2 and integ. section (b)

-----  
From analysis, chord rotation  $\theta = 1.6608452E-008$   
 $y = (M_y \cdot L_s / 3) / E I_{eff} = 0.00168892$  ((4.29), Biskinis Phd))  
 $M_y = 3.3311E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 819.0609  
From table 10.5, ASCE 41\_17:  $E I_{eff} = \text{factor} \cdot E_c \cdot I_g = 5.3849E+013$   
factor = 0.30  
Ag = 237500.00  
fc' = 33.00  
N = 9995.934  
 $E_c \cdot I_g = 1.7950E+014$   
-----  
-----

Calculation of Yielding Moment  $M_y$

Calculation of  $\phi_y$  and  $M_y$  according to Annex 7 -

-----  
 $y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 4.3412800E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b / l_d)^{2/3}) = 311.2112$   
d = 557.00  
y = 0.35649464  
A = 0.02983044  
B = 0.01921269  
with pt = 0.01254381  
pc = 0.00595605  
pv = 0.01109992  
N = 9995.934  
b = 250.00  
" = 0.07719928  
 $y_{comp} = 1.1115910E-005$   
with fc = 33.00  
Ec = 26999.444  
y = 0.3553296  
A = 0.02943664  
B = 0.01898202  
with Es = 200000.00  
-----  
-----

Calculation of ratio  $l_b / l_d$

Inadequate Lap Length with  $l_b / l_d = 0.30$

-----  
End Of Calculation of Shear Capacity for element: column LC1 of floor 1  
At local axis: 3  
Integration Section: (b)  
-----

**Calculation No. 16**

column C1, Floor 1

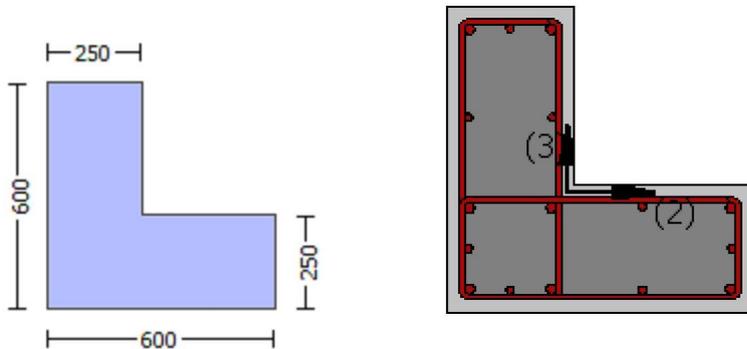
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\theta_u$ )

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: rclcs

Constant Properties

Knowledge Factor,  $\gamma = 0.86$

Mean strength values are used for both shear and moment calculations.

Consequently:

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

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

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with  $l_o/l_{ou,min} = 0.30$

No FRP Wrapping

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 0.33706551$   
EDGE -B-  
Shear Force,  $V_b = -0.33706551$   
BOTH EDGES  
Axial Force,  $F = -8883.863$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 4121.77$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten} = 1746.726$   
-Compression:  $A_{sc,com} = 829.3805$   
-Middle:  $A_{sc,mid} = 1545.664$

-----  
-----  
Calculation of Shear Capacity ratio,  $V_e/V_r = 0.71876853$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 358969.728$   
with  
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 5.3845E+008$   
 $Mu_{1+} = 5.3845E+008$ , 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  
 $Mu_{1-} = 2.9011E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 5.3845E+008$   
 $Mu_{2+} = 5.3845E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination  
 $Mu_{2-} = 2.9011E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

-----  
Calculation of  $Mu_{1+}$   
-----

-----  
Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\phi_u = 1.2895006E-005$   
 $M_u = 5.3845E+008$   
-----

with full section properties:

$b = 250.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00193327$   
 $N = 8883.863$   
 $f_c = 33.00$   
 $\alpha_1 = 0.85$   
Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00616264$   
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY:  $\phi_u = 0.00616264$   
 $\phi_{c1} = 0.00443103$   
 $\phi_{c2} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$   
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.  
 $A_{conf,max} = 169100.00$  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.  
 $A_{conf,min} = 98400.00$  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.  
 $A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $\phi_{c3} = \text{Min}(\phi_{c3,x}, \phi_{c3,y}) = 0.00321875$   
Expression ((5.4d), TBDY) for  $\phi_{c3}$  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) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 150.00

fywe = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.30

su1 =  $0.4 * esu1\_nominal$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 =  $0.4 * esu2\_nominal$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.30

suv =  $0.4 * esuv\_nominal$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY  
For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 =  $Asl,ten / (b * d) * (fs1 / fc) = 0.14787021$

2 =  $Asl,com / (b * d) * (fs2 / fc) = 0.07021175$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.13084918$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.20564193$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09764293$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.18197092$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$  - RHS eq.(4.5) is satisfied

--->

$$s_u (4.8) = 0.28715809$$

$$\mu_u = M R_c (4.15) = 5.3845E+008$$

$$u = s_u (4.1) = 1.2895006E-005$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{u1}$ -

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0873764E-005$$

$$\mu_u = 2.9011E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00080553$$

$$N = 8883.863$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.00616264$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.00616264$$

$$w_e (5.4c) = 0.00443103$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along } Y) = 1460.00$$

Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875  
Lstir (Length of stirrups along X) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

s = 150.00  
fywe = 694.45  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.002  
c = confinement factor = 1.00

y1 = 0.00140044  
sh1 = 0.0044814  
ft1 = 466.8167  
fy1 = 389.0139  
su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.30

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044  
sh2 = 0.0044814  
ft2 = 466.8167  
fy2 = 389.0139  
su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044  
shv = 0.0044814  
ftv = 466.8167  
fyv = 389.0139  
suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.30

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY  
For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0292549

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.06161259

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.05452049

and confined core properties:

b = 540.00

$d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 33.00$   
 $cc (5A.5, TBDY) = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03435585$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07235549$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0640268$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.15465327$   
 $Mu = MRc (4.14) = 2.9011E+008$   
 $u = su (4.1) = 1.0873764E-005$

-----  
 Calculation of ratio  $l_b/l_d$

-----  
 Inadequate Lap Length with  $l_b/l_d = 0.30$   
 -----  
 -----

-----  
 Calculation of  $Mu_{2+}$   
 -----

-----  
 Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 1.2895006E-005$   
 $Mu = 5.3845E+008$   
 -----

with full section properties:

$b = 250.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00193327$   
 $N = 8883.863$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00616264$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.00616264$   
 $w_e (5.4c) = 0.00443103$

$ase = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$   
 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.  
 $A_{conf,max} = 169100.00$  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.  
 $A_{conf,min} = 98400.00$  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.  
 $A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$   
 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)

-----  
 $p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$   
 $L_{stir}$  (Length of stirrups along Y) = 1460.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 237500.00  
 -----

$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$   
 $L_{stir}$  (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

s = 150.00

fywe = 694.45

fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb = 0.30

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb = 0.30

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.14787021

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.07021175

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.13084918

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 33.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.20564193$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09764293$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.18197092$$

Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied

--->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied

--->  
 $\mu_u$  (4.8) = 0.28715809  
 $M_u = M_{Rc}$  (4.15) = 5.3845E+008  
 $u = \mu_u$  (4.1) = 1.2895006E-005

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{u2}$

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0873764E-005$$

$$M_u = 2.9011E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00080553$$

$$N = 8883.863$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_{cu}: \mu_{cu}^* = \text{shear\_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.00616264$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_{cu} = 0.00616264$$

$$\mu_{we} \text{ (5.4c)} = 0.00443103$$

$$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.00321875$$

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)

$$\mu_{psh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$\mu_{psh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$s = 150.00$   
 $fy_{we} = 694.45$   
 $f_{ce} = 33.00$   
 From ((5.A.5), TBDY), TBDY:  $cc = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $y_1 = 0.00140044$   
 $sh_1 = 0.0044814$   
 $ft_1 = 466.8167$   
 $fy_1 = 389.0139$   
 $su_1 = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/ld = 0.30$   
 $su_1 = 0.4 * esu_1 \text{ nominal ((5.5), TBDY)} = 0.032$   
 From table 5A.1, TBDY:  $esu_1 \text{ nominal} = 0.08$ ,  
 For calculation of  $esu_1 \text{ nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
 characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs_1 = fs = 389.0139$   
 with  $Es_1 = Es = 200000.00$   
 $y_2 = 0.00140044$   
 $sh_2 = 0.0044814$   
 $ft_2 = 466.8167$   
 $fy_2 = 389.0139$   
 $su_2 = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/lb, \min = 0.30$   
 $su_2 = 0.4 * esu_2 \text{ nominal ((5.5), TBDY)} = 0.032$   
 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, ASCE41-17.  
 with  $fs_2 = fs = 389.0139$   
 with  $Es_2 = Es = 200000.00$   
 $y_v = 0.00140044$   
 $sh_v = 0.0044814$   
 $ft_v = 466.8167$   
 $fy_v = 389.0139$   
 $suv = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/ld = 0.30$   
 $suv = 0.4 * esuv \text{ nominal ((5.5), TBDY)} = 0.032$   
 From table 5A.1, TBDY:  $esuv \text{ nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv \text{ nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fsv = fs = 389.0139$   
 with  $Esv = Es = 200000.00$   
 $1 = Asl, \text{ten}/(b * d) * (fs_1 / fc) = 0.0292549$   
 $2 = Asl, \text{com}/(b * d) * (fs_2 / fc) = 0.06161259$   
 $v = Asl, \text{mid}/(b * d) * (fsv / fc) = 0.05452049$   
 and confined core properties:  
 $b = 540.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} \text{ (5A.2, TBDY)} = 33.00$   
 $cc \text{ (5A.5, TBDY)} = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = Asl, \text{ten}/(b * d) * (fs_1 / fc) = 0.03435585$   
 $2 = Asl, \text{com}/(b * d) * (fs_2 / fc) = 0.07235549$   
 $v = Asl, \text{mid}/(b * d) * (fsv / fc) = 0.0640268$

Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->  
 $\mu$  (4.9) = 0.15465327  
 $\mu$  = MRc (4.14) = 2.9011E+008  
 $u$  =  $\mu$  (4.1) = 1.0873764E-005

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
-----  
-----  
-----

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 499423.271$   
-----

Calculation of Shear Strength at edge 1,  $V_{r1} = 515023.161$   
 $V_{r1} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} * V_{Col0}$   
 $V_{Col0} = 515023.161$   
 $k_{nl} = 1$  (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).

-----  
 $\lambda = 1$  (normal-weight concrete)  
 $f_c' = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.9058$   
 $\mu = 470.1336$   
 $V_u = 0.33706551$   
 $d = 0.8 * h = 480.00$   
 $N_u = 8883.863$   
 $A_g = 150000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$   
where:  
 $V_{s1} = 279254.914$  is calculated for section web, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.3125$   
 $V_{s2} = 116356.214$  is calculated for section flange, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.75$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440:  $V_s + V_f \leq 457936.196$   
 $b_w = 250.00$   
-----

-----  
Calculation of Shear Strength at edge 2,  $V_{r2} = 499423.271$

$V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} * V_{Col0}$   
 $V_{Col0} = 499423.271$   
 $k_{nl} = 1$  (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).

-----  
 $\lambda = 1$  (normal-weight concrete)  
 $f_c' = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 3.34246$

$\mu_u = 540.7808$   
 $V_u = 0.33706551$   
 $d = 0.8 \cdot h = 480.00$   
 $N_u = 8883.863$   
 $A_g = 150000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$   
 where:  
 $V_{s1} = 279254.914$  is calculated for section web, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.3125$   
 $V_{s2} = 116356.214$  is calculated for section flange, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.75$   
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$   
 From (11-11), ACI 440:  $V_s + V_f \leq 457936.196$   
 $b_w = 250.00$

-----  
 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,  $\phi = 0.86$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 #####  
 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  
 New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
 #####  
 Max Height,  $H_{max} = 600.00$   
 Min Height,  $H_{min} = 250.00$   
 Max Width,  $W_{max} = 600.00$   
 Min Width,  $W_{min} = 250.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.00  
 Element Length,  $L = 3000.00$   
 Primary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Inadequate Lap Length with  $l_o/l_{o,u,min} = 0.30$   
 No FRP Wrapping

## Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = 0.33706551$

EDGE -B-

Shear Force,  $V_b = -0.33706551$

BOTH EDGES

Axial Force,  $F = -8883.863$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 4121.77$

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,  $V_e/V_r = 0.71876765$

Member Controlled by Flexure ( $V_e/V_r < 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 358969.728$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 5.3845E+008$

$Mu_{1+} = 5.3845E+008$ , 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

$Mu_{1-} = 2.9011E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 5.3845E+008$

$Mu_{2+} = 5.3845E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$Mu_{2-} = 2.9011E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of  $Mu_{1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.2895006E-005$

$M_u = 5.3845E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00193327$

$N = 8883.863$

$f_c = 33.00$

$\alpha_c$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.00616264$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.00616264$

$\phi_{we}$  (5.4c) = 0.00443103

$\alpha_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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 = 105733.333 is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00321875$

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)

-----  
 $psh_x \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00321875$

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

-----  
 $psh_y \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00321875$

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

-----  
 $s = 150.00$

$fy_{we} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.002$

$c = \text{confinement factor} = 1.00$

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$lo/lo_{min} = lb/ld = 0.30$

$su_1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_1 = fs = 389.0139$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$lo/lo_{min} = lb/lb_{min} = 0.30$

$su_2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_2 = fs = 389.0139$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$suv = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$lo/lo_{min} = lb/ld = 0.30$

$suv = 0.4 * esuv_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,

considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered

characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $f_{sv} = f_s = 389.0139$   
with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.14787021$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07021175$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.13084918$

and confined core properties:

$b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 33.00$   
 $cc (5A.5, TBDY) = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.20564193$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09764293$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.18197092$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$  - RHS eq.(4.5) is satisfied

--->

$su (4.8) = 0.28715809$

$Mu = MRc (4.15) = 5.3845E+008$

$u = su (4.1) = 1.2895006E-005$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
-----  
-----

-----  
Calculation of  $Mu_1$ -  
-----

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.0873764E-005$

$Mu = 2.9011E+008$   
-----

with full section properties:

$b = 600.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00080553$   
 $N = 8883.863$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$

Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00616264$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $cu = 0.00616264$

$w_e (5.4c) = 0.00443103$

$ase = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

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)

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00321875$$

$$Lstir (\text{Length of stirrups along Y}) = 1460.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 237500.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00321875$$

$$Lstir (\text{Length of stirrups along X}) = 1460.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 237500.00$$

$$s = 150.00$$

$$fywe = 694.45$$

$$fce = 33.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou,min = lb/d = 0.30$$

$$su1 = 0.4 * esu1\_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1\_nominal = 0.08,$$

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

$$y1, sh1,ft1,fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/d)^{2/3}), \text{ from 10.3.5, ASCE41-17.}$$

$$\text{with } fs1 = fs = 389.0139$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.30$$

$$su2 = 0.4 * esu2\_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2\_nominal = 0.08,$$

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

$$y1, sh1,ft1,fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/d)^{2/3}), \text{ from 10.3.5, ASCE41-17.}$$

$$\text{with } fs2 = fs = 389.0139$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou,min = lb/d = 0.30$$

$$suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esuv\_nominal = 0.08,$$

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

$$y1, sh1,ft1,fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/d)^{2/3}), \text{ from 10.3.5, ASCE41-17.}$$

$$\text{with } fsv = fs = 389.0139$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0292549$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.06161259$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.05452049$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03435585$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07235549$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0640268$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.15465327$$

$$M_u = M_{Rc} (4.14) = 2.9011E+008$$

$$u = s_u (4.1) = 1.0873764E-005$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $M_{u2+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.2895006E-005$$

$$M_u = 5.3845E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00193327$$

$$N = 8883.863$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.00616264$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.00616264$$

$$w_e (5.4c) = 0.00443103$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along } Y) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 150.00

fywe = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.30

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.30

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY  
For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.14787021

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.07021175

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.13084918

and confined core properties:

b = 190.00

d = 527.00

$d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 33.00$   
 $cc (5A.5, TBDY) = 0.002$   
 $c = \text{confinement factor} = 1.00$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.20564193$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09764293$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.18197092$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
 --->  
 $su (4.8) = 0.28715809$   
 $Mu = MRc (4.15) = 5.3845E+008$   
 $u = su (4.1) = 1.2895006E-005$

-----  
 Calculation of ratio  $l_b/l_d$

-----  
 Inadequate Lap Length with  $l_b/l_d = 0.30$   
 -----  
 -----

-----  
 Calculation of  $Mu_2$ -  
 -----  
 -----

-----  
 Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.0873764E-005$   
 $Mu = 2.9011E+008$

-----  
 with full section properties:

$b = 600.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00080553$   
 $N = 8883.863$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.00616264$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.00616264$   
 $w_e (5.4c) = 0.00443103$

$ase = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  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.

$A_{conf,min} = 98400.00$  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.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

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)

-----  
 $p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00  
 -----

$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

Lstir (Length of stirrups along X) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

s = 150.00

fywe = 694.45

fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY  
For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0292549

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.06161259

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.05452049

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 33.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00  
1 =  $Asl,ten/(b*d)*(fs1/fc) = 0.03435585$   
2 =  $Asl,com/(b*d)*(fs2/fc) = 0.07235549$   
v =  $Asl,mid/(b*d)*(fsv/fc) = 0.0640268$

Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)

--->  
v <  $v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->  
su (4.9) = 0.15465327  
Mu = MRc (4.14) = 2.9011E+008  
u = su (4.1) = 1.0873764E-005

-----  
Calculation of ratio lb/d

-----  
Inadequate Lap Length with lb/d = 0.30  
-----  
-----  
-----

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 499423.877$   
-----

Calculation of Shear Strength at edge 1,  $V_{r1} = 515022.351$   
 $V_{r1} = V_{Co1} ((10.3), \text{ASCE } 41-17) = knl * V_{Co10}$   
 $V_{Co10} = 515022.351$   
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)  
 $fc' = 33.00$ , but  $fc^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.90582$   
Mu = 470.1368  
Vu = 0.33706551  
d =  $0.8*h = 480.00$   
Nu = 8883.863  
Ag = 150000.00  
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$   
where:  
 $V_{s1} = 116356.214$  is calculated for section web, with:  
d = 200.00  
Av = 157079.633  
fy = 555.56  
s = 150.00  
 $V_{s1}$  is multiplied by Col1 = 1.00  
s/d = 0.75  
 $V_{s2} = 279254.914$  is calculated for section flange, with:  
d = 480.00  
Av = 157079.633  
fy = 555.56  
s = 150.00  
 $V_{s2}$  is multiplied by Col2 = 1.00  
s/d = 0.3125  
Vf ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440:  $V_s + V_f \leq 457936.196$   
bw = 250.00  
-----

-----  
Calculation of Shear Strength at edge 2,  $V_{r2} = 499423.877$   
 $V_{r2} = V_{Co2} ((10.3), \text{ASCE } 41-17) = knl * V_{Co20}$   
 $V_{Co20} = 499423.877$   
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)  
 $f_c' = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 3.34244$   
 $\mu_u = 540.7776$   
 $V_u = 0.33706551$   
 $d = 0.8 \cdot h = 480.00$   
 $N_u = 8883.863$   
 $A_g = 150000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 395611.129$   
where:  
 $V_{s1} = 116356.214$  is calculated for section web, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.75$   
 $V_{s2} = 279254.914$  is calculated for section flange, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.3125$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 0.00  
From (11-11), ACI 440:  $V_s + V_f \leq 457936.196$   
 $b_w = 250.00$   
-----

-----  
End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At local axis: 2  
-----

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Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1  
At local axis: 3  
Integration Section: (b)  
Section Type: rclcs

Constant Properties

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Knowledge Factor,  $\gamma = 0.86$   
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.  
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Max Height,  $H_{max} = 600.00$   
Min Height,  $H_{min} = 250.00$   
Max Width,  $W_{max} = 600.00$   
Min Width,  $W_{min} = 250.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
No FRP Wrapping  
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Stepwise Properties

Bending Moment,  $M = 347029.948$   
Shear Force,  $V2 = 5326.433$   
Shear Force,  $V3 = -341.7795$   
Axial Force,  $F = -9995.934$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 4121.77$   
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,  $Db_L = 17.71429$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0^*$   $u = 0.02168114$   
 $u = y + p = 0.02168114$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00061861$  ((4.29), Biskinis Phd))  
 $M_y = 3.3311E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) =  $300.00$   
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 5.3849E+013$   
 $factor = 0.30$   
 $A_g = 237500.00$   
 $fc' = 33.00$   
 $N = 9995.934$   
 $E_c * I_g = 1.7950E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{,ten}, y_{,com})$   
 $y_{,ten} = 4.3412800E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / d)^{2/3}) = 311.2112$   
 $d = 557.00$   
 $y = 0.35649464$   
 $A = 0.02983044$   
 $B = 0.01921269$   
with  $pt = 0.01254381$   
 $pc = 0.00595605$   
 $pv = 0.01109992$   
 $N = 9995.934$   
 $b = 250.00$   
 $" = 0.07719928$   
 $y_{,comp} = 1.1115910E-005$   
with  $fc = 33.00$   
 $E_c = 26999.444$   
 $y = 0.3553296$   
 $A = 0.02943664$   
 $B = 0.01898202$   
with  $E_s = 200000.00$

Calculation of ratio  $l_b / d$

Inadequate Lap Length with  $l_b / d = 0.30$

- Calculation of  $\rho$  -

From table 10-8:  $\rho = 0.02106253$

with:

- Columns not controlled by inadequate development or splicing along the clear height because  $l_b/l_d \geq 1$   
shear control ratio  $V_{yE}/V_{CoIE} = 0.71876765$

$d = 557.00$

$s = 0.00$

$t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.00$

$A_v = 78.53982$ , is the area of every stirrup

$L_{stir} = 1460.00$ , 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.

$N_{UD} = 9995.934$

$A_g = 237500.00$

$f_{cE} = 33.00$

$f_{ytE} = f_{ylE} = 0.00$

$\rho_l = \text{Area\_Tot\_Long\_Rein}/(b*d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_{cE} = 33.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)