

Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

column C1, Floor 1

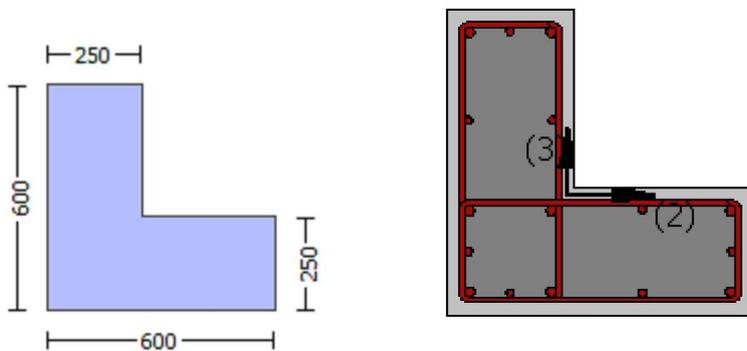
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity 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, $\gamma = 1.00$

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

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

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

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

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

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

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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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

No FRP Wrapping

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -8.4841E+006$

Shear Force, $V_a = -2791.209$

EDGE -B-

Bending Moment, $M_b = 107614.564$

Shear Force, $V_b = 2791.209$

BOTH EDGES

Axial Force, $F = -9391.552$

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, $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 204334.901$

V_n ((10.3), ASCE 41-17) = $k_n l V_{CoI} = 204334.901$

$V_{CoI} = 204334.901$

$k_n l = 1.00$

displacement_ductility_demand = 0.00733382

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

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

$f'_c = 16.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$M_u = 8.4841E+006$

$V_u = 2791.209$

$d = 0.8 \cdot h = 480.00$

$N_u = 9391.552$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 143615.664$

where:

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

$d = 200.00$

$A_v = 157079.633$

$f_y = 400.00$
 $s = 210.00$
Vs1 is multiplied by Col1 = 0.00
 $s/d = 1.05$
Vs2 = 143615.664 is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 210.00$
Vs2 is multiplied by Col2 = 1.00
 $s/d = 0.4375$
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: $V_s + V_f \leq 318865.838$
 $b_w = 250.00$

displacement ductility demand is calculated as δ / y

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

From analysis, chord rotation = $8.2960788E-005$
 $y = (M_y * L_s / 3) / E_{eff} = 0.01131209$ ((4.29), Biskinis Phd))
 $M_y = 4.6805E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3039.571
From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 4.1921E+013$
factor = 0.30
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9391.552$
 $E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 6.4707158E-006$
with $f_y = 444.44$
 $d = 557.00$
 $y = 0.3834396$
 $A = 0.02975153$
 $B = 0.01913377$
with $p_t = 0.01254381$
 $p_c = 0.00595605$
 $p_v = 0.01109992$
 $N = 9391.552$
 $b = 250.00$
 $\rho = 0.07719928$
 $y_{comp} = 8.0247450E-006$
with $f_c = 20.00$
 $E_c = 21019.039$
 $y = 0.38318033$
 $A = 0.02940289$
 $B = 0.01898202$
with $E_s = 200000.00$

Calculation of ratio l_b/d

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

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

Integration Section: (a)

Calculation No. 2

column C1, Floor 1

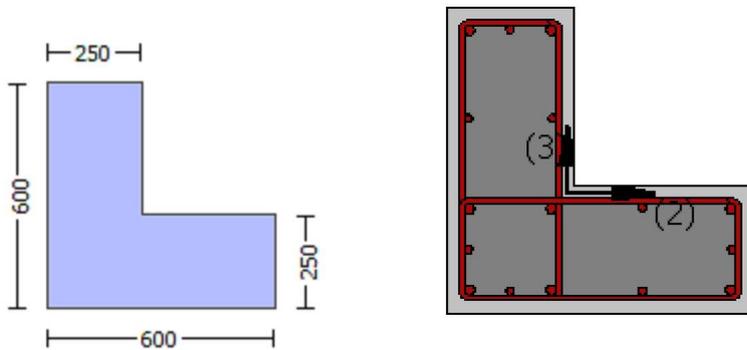
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_r)

Edge: Start

Local Axis: (2)



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

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rdcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

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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, $L = 3000.00$

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

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = 0.00016213$
EDGE -B-
Shear Force, $V_b = -0.00016213$
BOTH EDGES
Axial Force, $F = -8883.864$
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: $A_{sl,mid} = 1545.664$

Calculation of Shear Capacity ratio , $V_e/V_r = 1.93617$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 440088.681$
with
 $M_{pr1} = \max(\mu_{1+}, \mu_{1-}) = 6.6013E+008$
 $\mu_{1+} = 5.3907E+008$, 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
 $\mu_{1-} = 6.6013E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \max(\mu_{2+}, \mu_{2-}) = 6.6013E+008$
 $\mu_{2+} = 5.3907E+008$, 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
 $\mu_{2-} = 6.6013E+008$, 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 μ_{1+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:
 $\mu = 8.2702663E-006$
 $\mu_u = 5.3907E+008$

with full section properties:

$b = 250.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.0031899$
 $N = 8883.864$
 $f_c = 20.00$
 $\omega (5A.5, TBDY) = 0.002$
Final value of μ_u : $\mu_u^* = \text{shear_factor} * \max(\mu_u, \omega) = 0.0056977$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\mu_u = 0.0056977$
 $\omega_e (5.4c) = 0.00301868$
 $\mu_{ase} = \max(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$
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.

$A_{conf,min} = 71100.00$ 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 210.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

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

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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

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

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

with $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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

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

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

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lo_{u,min} = lb/d = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

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

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.34843568

2 = Asl,com/(b*d)*(fs2/fc) = 0.16544428

v = Asl,mid/(b*d)*(fsv/fc) = 0.30832797

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.48456674

2 = Asl,com/(b*d)*(fs2/fc) = 0.23008205

v = Asl,mid/(b*d)*(fsv/fc) = 0.42878928

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 not satisfied

Case/Assumption Rejected.

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

' satisfies Eq. (4.4)

v < s,y1 - LHS eq.(4.7) is not satisfied

v < vc,y1 - RHS eq.(4.6) is satisfied

cu (4.10) = 0.35203969

MRC (4.17) = 6.2207E+008

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

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: bo, do, d'o

- N, 1, 2, v normalised to bo*do, instead of b*d

- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu

Subcase: Rupture of tension steel

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

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

Subcase rejected

New Subcase: Failure of compression zone

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

v* < v*c,y1 - RHS eq.(4.6) is satisfied

*cu (4.10) = 0.4588808

MRO (4.17) = 5.3907E+008

u = cu (4.2) = 8.2702663E-006

Mu = MRo

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

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

$\mu = 6.8293729E-005$

Mu = 6.6013E+008

with full section properties:

b = 600.00

d = 557.00

d' = 43.00

v = 0.00132912

N = 8883.864

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu, \text{cc}) = 0.0056977$

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

From (5.4b), TBDY: $\mu = 0.0056977$

we (5.4c) = 0.00301868

ase = $\text{Max}(((\text{Aconf,max}-\text{AnoConf})/\text{Aconf,max}) * (\text{Aconf,min}/\text{Aconf,max}), 0) = 0.15755901$

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 = 71100.00 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 = $\text{Min}(\text{psh,x}, \text{psh,y}) = 0.00229911$

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) = $\text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00229911$

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = $\text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00229911$

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 210.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

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

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y2, sh2,ft2,fy2, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

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

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.06893512

2 = Asl,com/(b*d)*(fs2/fc) = 0.14518153

v = Asl,mid/(b*d)*(fsv/fc) = 0.12846999

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.0809548

2 = Asl,com/(b*d)*(fs2/fc) = 0.17049571

v = Asl,mid/(b*d)*(fsv/fc) = 0.1508703

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) = 0.15877155

Mu = MRc (4.15) = 6.6013E+008

u = su (4.1) = 6.8293729E-005

Calculation of ratio l_b/d

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

Calculation of μ_{2+}

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

$$\mu = 8.2702663E-006$$

$$\mu_u = 5.3907E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, c_c) = 0.0056977$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.0056977$$

$$\mu_{ue} \text{ (5.4c)} = 0.00301868$$

$$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.00229911$$

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)

$$\mu_{psh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$\mu_{psh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

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

with $fs1 = fs = 555.55$

with $Es1 = Es = 200000.00$

$y2 = 0.00231479$

$sh2 = 0.008$

$ft2 = 666.66$

$fy2 = 555.55$

$su2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$

and also multiplied by the $shear_factor$ according to 15.7.1.4, with

$Shear_factor = 1.00$

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

$su2 = 0.4*esu2_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

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

with $fs2 = fs = 555.55$

with $Es2 = Es = 200000.00$

$yv = 0.00231479$

$shv = 0.008$

$ftv = 666.66$

$fyv = 555.55$

$suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$

and also multiplied by the $shear_factor$ according to 15.7.1.4, with

$Shear_factor = 1.00$

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

$suv = 0.4*esuv_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

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

For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered

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

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

with $fsv = fs = 555.55$

with $Esv = Es = 200000.00$

$1 = Asl, ten / (b * d) * (fs1 / fc) = 0.34843568$

$2 = Asl, com / (b * d) * (fs2 / fc) = 0.16544428$

$v = Asl, mid / (b * d) * (fsv / fc) = 0.30832797$

and confined core properties:

$b = 190.00$

$d = 527.00$

$d' = 13.00$

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

$c =$ confinement factor = 1.00

$1 = Asl, ten / (b * d) * (fs1 / fc) = 0.48456674$

$2 = Asl, com / (b * d) * (fs2 / fc) = 0.23008205$

$v = Asl, mid / (b * d) * (fsv / fc) = 0.42878928$

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 not satisfied

Case/Assumption Rejected.

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

' satisfies Eq. (4.4)

$v < s, y1$ - LHS eq.(4.7) is not satisfied

$v < vc, y1$ - RHS eq.(4.6) is satisfied

--->

cu (4.10) = 0.35203969
MRc (4.17) = 6.2207E+008

--->

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

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu

--->

Subcase: Rupture of tension steel

--->

$v^* < v^*s_y2$ - LHS eq.(4.5) is not satisfied

--->

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

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

$v^* < v^*c_y2$ - LHS eq.(4.6) is not satisfied

--->

$v^* < v^*c_y1$ - RHS eq.(4.6) is satisfied

--->

*cu (4.10) = 0.4588808

MRO (4.17) = 5.3907E+008

--->

u = cu (4.2) = 8.2702663E-006

Mu = MRO

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

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

u = 6.8293729E-005

Mu = 6.6013E+008

with full section properties:

b = 600.00

d = 557.00

d' = 43.00

v = 0.00132912

N = 8883.864

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0056977$

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

From (5.4b), TBDY: $cu = 0.0056977$

we (5.4c) = 0.00301868

ase = $\text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.15755901$

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 = 71100.00 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).

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00229911$

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)

 $psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

 $psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 210.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/l_d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs/1.2, from table 5.1, TBDY.

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

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs/1.2, from table 5.1, TBDY.

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

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/l_d = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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 $f_{sv} = f_s = 555.55$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.06893512$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.14518153$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.12846999$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 20.00$

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

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

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0809548$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.17049571$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.1508703$

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

--->

$su (4.8) = 0.15877155$

$Mu = MRc (4.15) = 6.6013E+008$

$u = su (4.1) = 6.8293729E-005$

Calculation of ratio lb/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227298.208$

Calculation of Shear Strength at edge 1, $V_{r1} = 227298.208$

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

$V_{Col0} = 227298.208$

$knl = 1$ (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)

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

$M/Vd = 4.00$

$Mu = 47.14131$

$Vu = 0.00016213$

$d = 0.8 \cdot h = 480.00$

$Nu = 8883.864$

$Ag = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 159571.364$

where:

$V_{s1} = 159571.364$ is calculated for section web, with:

$d = 480.00$

$Av = 157079.633$

$fy = 444.44$

$s = 210.00$

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

$s/d = 0.4375$

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

$d = 200.00$

$Av = 157079.633$

$fy = 444.44$

$s = 210.00$

Vs2 is multiplied by Col2 = 0.00
s/d = 1.05
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 356502.845
bw = 250.00

Calculation of Shear Strength at edge 2, Vr2 = 227298.208
Vr2 = VCol ((10.3), ASCE 41-17) = knl*VCol0
VCol0 = 227298.208
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' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 47.14134
Vu = 0.00016213
d = 0.8*h = 480.00
Nu = 8883.864
Ag = 150000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 159571.364

where:
Vs1 = 159571.364 is calculated for section web, with:
d = 480.00
Av = 157079.633
fy = 444.44
s = 210.00

Vs1 is multiplied by Col1 = 1.00
s/d = 0.4375

Vs2 = 0.00 is calculated for section flange, with:
d = 200.00
Av = 157079.633
fy = 444.44
s = 210.00

Vs2 is multiplied by Col2 = 0.00
s/d = 1.05
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 356502.845
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: rdcs

Constant Properties

Knowledge Factor, = 1.00
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00
Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44
Concrete Elasticity, Ec = 21019.039
Steel Elasticity, Es = 200000.00

#####

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

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

#####

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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

No FRP Wrapping

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = 0.00016213$

EDGE -B-

Shear Force, $V_b = -0.00016213$

BOTH EDGES

Axial Force, $F = -8883.864$

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, $V_e/V_r = 1.93617$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 440088.681$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 6.6013E+008$

$M_{u1+} = 5.3907E+008$, 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

$M_{u1-} = 6.6013E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 6.6013E+008$

$M_{u2+} = 5.3907E+008$, 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

$M_{u2-} = 6.6013E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 8.2702663E-006$

$M_u = 5.3907E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0056977$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0056977$$

$$w_e \text{ (5.4c)} = 0.00301868$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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

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.

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

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

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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

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

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 555.55$
 with $Es_2 = Es = 200000.00$
 $yv = 0.00231479$
 $shv = 0.008$
 $ftv = 666.66$
 $fyv = 555.55$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, \text{min} = lb/d = 1.00$
 $suv = 0.4 \cdot esuv_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$
 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 $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 555.55$
 with $Esv = Es = 200000.00$
 $1 = Asl, \text{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.34843568$
 $2 = Asl, \text{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.16544428$
 $v = Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.30832797$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, \text{TBDY}) = 20.00$
 $cc (5A.5, \text{TBDY}) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = Asl, \text{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.48456674$
 $2 = Asl, \text{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.23008205$
 $v = Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.42878928$
 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 not satisfied
 --->
 Case/Assumption Rejected.
 --->
 New Case/Assumption: Unconfined full section - Spalling of concrete cover
 ' satisfies Eq. (4.4)
 --->
 $v < s, y_1$ - LHS eq.(4.7) is not satisfied
 --->
 $v < vc, y_1$ - RHS eq.(4.6) is satisfied
 --->
 $cu (4.10) = 0.35203969$
 $MRC (4.17) = 6.2207E+008$
 --->
 New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
 In expressions below, the following modifications have been made
 - b, d, d' replaced by geometric parameters of the core: $bo, do, d'o$
 - $N, 1, 2, v$ normalised to $bo \cdot do$, instead of $b \cdot d$
 - - parameters of confined concrete, fcc, cc , used in lieu of fc, ecu
 --->
 Subcase: Rupture of tension steel
 --->
 $v^* < v^* s, y_2$ - LHS eq.(4.5) is not satisfied
 --->
 $v^* < v^* s, c$ - LHS eq.(4.5) is not satisfied
 --->
 Subcase rejected
 --->
 New Subcase: Failure of compression zone

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

--->
 $v^* < v^*c,y1$ - RHS eq.(4.6) is satisfied

--->
 $*cu$ (4.10) = 0.4588808
MRo (4.17) = 5.3907E+008

--->
 $u = cu$ (4.2) = 8.2702663E-006
Mu = MRo

Calculation of ratio lb/d

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

Calculation of Mu1-

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

$u = 6.8293729E-005$
Mu = 6.6013E+008

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00132912$
 $N = 8883.864$

$fc = 20.00$
 co (5A.5, TBDY) = 0.002
Final value of cu : $cu^* = shear_factor * Max(cu, cc) = 0.0056977$

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

From (5.4b), TBDY: $cu = 0.0056977$

we (5.4c) = 0.00301868

$ase = Max(((Aconf,max - AnoConf)/Aconf,max) * (Aconf,min/Aconf,max), 0) = 0.15755901$

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.

$Aconf,min = 71100.00$ 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).

$psh,min = Min(psh,x, psh,y) = 0.00229911$

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) = $Lstir * Astir / (Asec * s) = 0.00229911$

$Lstir$ (Length of stirrups along Y) = 1460.00

$Astir$ (stirrups area) = 78.53982

$Asec$ (section area) = 237500.00

 psh,y ((5.4d), TBDY) = $Lstir * Astir / (Asec * s) = 0.00229911$

$Lstir$ (Length of stirrups along X) = 1460.00

$Astir$ (stirrups area) = 78.53982

$Asec$ (section area) = 237500.00

 $s = 210.00$

$fywe = 555.55$

$fce = 20.00$

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

$y1 = 0.00231479$

$sh1 = 0.008$

$ft1 = 666.66$

$fy1 = 555.55$

$su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

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

with $fs1 = fs = 555.55$

with $Es1 = Es = 200000.00$

$y2 = 0.00231479$

$sh2 = 0.008$

$ft2 = 666.66$

$fy2 = 555.55$

$su2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

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

with $fs2 = fs = 555.55$

with $Es2 = Es = 200000.00$

$yv = 0.00231479$

$shv = 0.008$

$ftv = 666.66$

$fyv = 555.55$

$suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

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

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

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

with $fsv = fs = 555.55$

with $Esv = Es = 200000.00$

$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.06893512$

$2 = Asl,com / (b * d) * (fs2 / fc) = 0.14518153$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.12846999$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 20.00$

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

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

$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0809548$

$2 = Asl,com / (b * d) * (fs2 / fc) = 0.17049571$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.1508703$

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

--->

$$s_u(4.8) = 0.15877155$$

$$M_u = M_{Rc}(4.15) = 6.6013E+008$$

$$u = s_u(4.1) = 6.8293729E-005$$

Calculation of ratio l_b/l_d

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

Calculation of M_{u2+}

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

$$u = 8.2702663E-006$$

$$M_u = 5.3907E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0056977$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0056977$$

$$w_e(5.4c) = 0.00301868$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$$

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)

$$p_{sh,x}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$p_{sh,y}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

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

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.34843568

2 = Asl,com/(b*d)*(fs2/fc) = 0.16544428

v = Asl,mid/(b*d)*(fsv/fc) = 0.30832797

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.48456674

2 = Asl,com/(b*d)*(fs2/fc) = 0.23008205

v = Asl,mid/(b*d)*(fsv/fc) = 0.42878928

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 not satisfied

--->

Case/Assumption Rejected.

--->

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

--->

$v < s_y1$ - LHS eq.(4.7) is not satisfied

--->

$v < v_c y1$ - RHS eq.(4.6) is satisfied

--->

c_u (4.10) = 0.35203969

MRC (4.17) = 6.2207E+008

--->

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

In expressions below, the following modifications have been made

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

--->

Subcase: Rupture of tension steel

--->

$v^* < v^* s_y2$ - LHS eq.(4.5) is not satisfied

--->

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

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

$v^* < v^* c_y2$ - LHS eq.(4.6) is not satisfied

--->

$v^* < v^* c_y1$ - RHS eq.(4.6) is satisfied

--->

* c_u (4.10) = 0.4588808

MRO (4.17) = 5.3907E+008

--->

$u = c_u$ (4.2) = 8.2702663E-006

$\mu_u = MRO$

Calculation of ratio l_b/d

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

Calculation of μ_u

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

$u = 6.8293729E-005$

$\mu_u = 6.6013E+008$

with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 43.00$

$\nu = 0.00132912$

$N = 8883.864$

$f_c = 20.00$

c_o (5A.5, TBDY) = 0.002

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0056977$

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

From (5.4b), TBDY: $c_u = 0.0056977$

w_e (5.4c) = 0.00301868

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$

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.

$A_{conf,min} = 71100.00$ 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 210.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

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

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

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

$su_1 = 0.4 * esu1_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

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

with $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lou,min = lb/l_{b,min} = 1.00$

$su_2 = 0.4 * esu2_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

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

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_0/l_{0u,min} = l_b/l_d = 1.00$

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

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 γ_v , sh_v, ft_v, f_{y1} , it is considered
characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

γ_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 $f_{sv} = f_s = 555.55$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.06893512$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.14518153$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.12846999$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 20.00$

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

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

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0809548$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.17049571$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.1508703$

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

$su (4.8) = 0.15877155$

$Mu = MRc (4.15) = 6.6013E+008$

$u = su (4.1) = 6.8293729E-005$

Calculation of ratio l_b/l_d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227298.208$

Calculation of Shear Strength at edge 1, $V_{r1} = 227298.208$

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

$V_{Co10} = 227298.208$

$knl = 1$ (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)

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

$M/Vd = 4.00$

$Mu = 47.13723$

$Vu = 0.00016213$

$d = 0.8 \cdot h = 480.00$

$Nu = 8883.864$

$Ag = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 159571.364$

where:

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

$d = 200.00$

$Av = 157079.633$

fy = 444.44
s = 210.00
Vs1 is multiplied by Col1 = 0.00
s/d = 1.05
Vs2 = 159571.364 is calculated for section flange, with:
d = 480.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs2 is multiplied by Col2 = 1.00
s/d = 0.4375
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 356502.845
bw = 250.00

Calculation of Shear Strength at edge 2, Vr2 = 227298.208
Vr2 = VCol ((10.3), ASCE 41-17) = knl*VCol0
VCol0 = 227298.208
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' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 47.13721
Vu = 0.00016213
d = 0.8*h = 480.00
Nu = 8883.864
Ag = 150000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 159571.364
where:
Vs1 = 0.00 is calculated for section web, with:
d = 200.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs1 is multiplied by Col1 = 0.00
s/d = 1.05
Vs2 = 159571.364 is calculated for section flange, with:
d = 480.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs2 is multiplied by Col2 = 1.00
s/d = 0.4375
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 356502.845
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, = 1.00

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/l_d >= 1$)

No FRP Wrapping

Stepwise Properties

Bending Moment, $M = -208162.641$

Shear Force, $V_2 = -2791.209$

Shear Force, $V_3 = 96.12431$

Axial Force, $F = -9391.552$

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, $DbL = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.00805935$

$u = y + p = 0.00805935$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00805935$ ((4.29), Biskinis Phd))

$M_y = 4.6805E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 2165.557

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1921E+013$

factor = 0.30

$A_g = 237500.00$

$f_c' = 20.00$

$N = 9391.552$

$E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$y_{ten} = 6.4707158E-006$

with $f_y = 444.44$

$d = 557.00$

$y = 0.3834396$

A = 0.02975153
B = 0.01913377
with pt = 0.01254381
pc = 0.00595605
pv = 0.01109992
N = 9391.552
b = 250.00
" = 0.07719928
y_comp = 8.0247450E-006
with fc = 20.00
Ec = 21019.039
y = 0.38318033
A = 0.02940289
B = 0.01898202
with Es = 200000.00

Calculation of ratio l_b/d

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

- Calculation of p -

From table 10-8: $p = 0.00$

with:

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

shear control ratio $V_y E / V_{CoI} E = 1.93617$

$d = 557.00$

$s = 0.00$

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

$A_v = 78.53982$, 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.

$N_{UD} = 9391.552$

$A_g = 237500.00$

$f_{cE} = 20.00$

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

$p_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_{cE} = 20.00$

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

At local axis: 2

Integration Section: (a)

Calculation No. 3

column C1, Floor 1

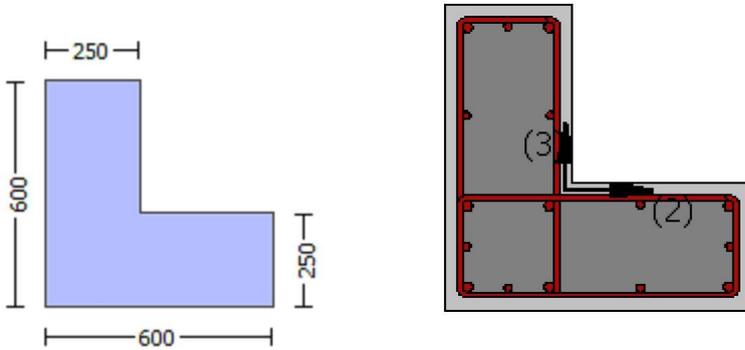
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

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: rclcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

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

#####

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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

No FRP Wrapping

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -208162.641$

Shear Force, $V_a = 96.12431$

EDGE -B-

Bending Moment, $M_b = -79153.178$

Shear Force, $V_b = -96.12431$

BOTH EDGES

Axial Force, $F = -9391.552$

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: $A_{s,mid} = 1545.664$

Mean Diameter of Tension Reinforcement, $D_{bL,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 204334.901$

V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoIO} = 204334.901$

$V_{CoI} = 204334.901$

$k_n = 1.00$

displacement ductility demand = 0.00385927

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

= 1 (normal-weight concrete)

$f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$M_u = 208162.641$

$V_u = 96.12431$

$d = 0.8 \cdot h = 480.00$

$N_u = 9391.552$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 143615.664$

where:

$V_{s1} = 143615.664$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 210.00$

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

$s/d = 0.4375$

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

$d = 200.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 210.00$

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

$s/d = 1.05$

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

From (11-11), ACI 440: $V_s + V_f \leq 318865.838$

$b_w = 250.00$

displacement ductility demand is calculated as δ / y

- Calculation of δ / y for END A -

for rotation axis 2 and integ. section (a)

From analysis, chord rotation = 3.1103185E-005

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00805935$ ((4.29), Biskinis Phd)

$M_y = 4.6805E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 2165.557
From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 4.1921E+013$
factor = 0.30
Ag = 237500.00
fc' = 20.00
N = 9391.552
 $E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

 $y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 6.4707158E-006$
with $f_y = 444.44$
d = 557.00
y = 0.3834396
A = 0.02975153
B = 0.01913377
with $p_t = 0.01254381$
pc = 0.00595605
pv = 0.01109992
N = 9391.552
b = 250.00
" = 0.07719928
 $y_{comp} = 8.0247450E-006$
with $f_c = 20.00$
Ec = 21019.039
y = 0.38318033
A = 0.02940289
B = 0.01898202
with $E_s = 200000.00$

Calculation of ratio I_b/I_d

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

End Of Calculation of Shear Capacity for element: column LC1 of floor 1
At local axis: 3
Integration Section: (a)

Calculation No. 4

column C1, Floor 1

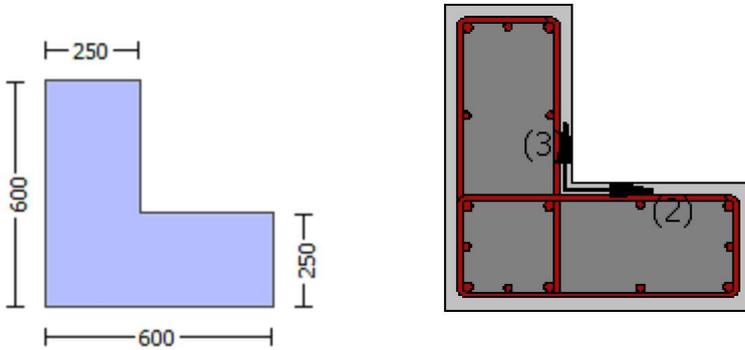
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_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, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

No FRP Wrapping

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 0.00016213$
EDGE -B-
Shear Force, $V_b = -0.00016213$
BOTH EDGES
Axial Force, $F = -8883.864$
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, $V_e/V_r = 1.93617$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 440088.681$
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 6.6013E+008$
 $M_{u1+} = 5.3907E+008$, 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
 $M_{u1-} = 6.6013E+008$, 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
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 6.6013E+008$
 $M_{u2+} = 5.3907E+008$, 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
 $M_{u2-} = 6.6013E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 8.2702663E-006$
 $M_u = 5.3907E+008$

with full section properties:

$b = 250.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.0031899$
 $N = 8883.864$
 $f_c = 20.00$
 α_1 (5A.5, TBDY) = 0.002
Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0056977$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_u = 0.0056977$
 ϕ_w (5.4c) = 0.00301868
 $\alpha_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.15755901$
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.
 $A_{conf,min} = 71100.00$ 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).
 $\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00229911$
Expression ((5.4d), TBDY) for $\phi_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00229911

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) = 0.00229911

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 210.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

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

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

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

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.34843568

2 = Asl,com/(b*d)*(fs2/fc) = 0.16544428

$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.30832797$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.48456674$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.23008205$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.42878928$
 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 not satisfied
 --->
 Case/Assumption Rejected.
 --->
 New Case/Assumption: Unconfined full section - Spalling of concrete cover
 ' satisfies Eq. (4.4)
 --->
 $v < s_{y1}$ - LHS eq.(4.7) is not satisfied
 --->
 $v < v_{c,y1}$ - RHS eq.(4.6) is satisfied
 --->
 $c_u (4.10) = 0.35203969$
 $M_{Rc} (4.17) = 6.2207E+008$
 --->
 New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
 In expressions below, the following modifications have been made
 - b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o
 - $N, 1, 2, v$ normalised to b_o*d_o , instead of $b*d$
 - f_{cc}, cc parameters of confined concrete, f_{cc}, cc , used in lieu of f_c, e_{cu}
 --->
 Subcase: Rupture of tension steel
 --->
 $v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied
 --->
 $v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied
 --->
 Subcase rejected
 --->
 New Subcase: Failure of compression zone
 --->
 $v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied
 --->
 $v^* < v^*_{c,y1}$ - RHS eq.(4.6) is satisfied
 --->
 $*c_u (4.10) = 0.4588808$
 $M_{Ro} (4.17) = 5.3907E+008$
 --->
 $u = c_u (4.2) = 8.2702663E-006$
 $M_u = M_{Ro}$

 Calculation of ratio l_b/l_d

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

Calculation of M_{u1} -

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

$$\mu = 6.8293729E-005$$

$$\mu_u = 6.6013E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0056977$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.0056977$$

$$\phi_{ue} \text{ (5.4c)} = 0.00301868$$

$$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00229911$$

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)

$$\phi_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$\phi_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

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

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

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 $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

$$su_2 = 0.4 * esu_2_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_2_{nominal} = 0.08$,

For calculation of $esu_2_{nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_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.

$$\text{with } fs_2 = fs = 555.55$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

$$fy_v = 555.55$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

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

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

For calculation of $esuv_{nominal}$ and 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.

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

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

$$1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.06893512$$

$$2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.14518153$$

$$v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.12846999$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 20.00$$

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

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

$$1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.0809548$$

$$2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.17049571$$

$$v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.1508703$$

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

---->

$$su (4.8) = 0.15877155$$

$$Mu = MRc (4.15) = 6.6013E+008$$

$$u = su (4.1) = 6.8293729E-005$$

Calculation of ratio l_b/l_d

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

Calculation of Mu_{2+}

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

$$u = 8.2702663E-006$$

$$Mu = 5.3907E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0056977$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0056977$$

$$w_e \text{ (5.4c)} = 0.00301868$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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

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.

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

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

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00
 lo/lou,min = lb/lb,min = 1.00
 su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
 From table 5A.1, TBDY: esu2_nominal = 0.08,
 For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
 characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
 y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.
 with fs2 = fs = 555.55
 with Es2 = Es = 200000.00
 yv = 0.00231479
 shv = 0.008
 ftv = 666.66
 fyv = 555.55
 suv = 0.032
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 lo/lou,min = lb/d = 1.00
 suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
 From table 5A.1, TBDY: esuv_nominal = 0.08,
 considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
 For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
 characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
 y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.
 with fsv = fs = 555.55
 with Esv = Es = 200000.00
 1 = Asl,ten/(b*d)*(fs1/fc) = 0.34843568
 2 = Asl,com/(b*d)*(fs2/fc) = 0.16544428
 v = Asl,mid/(b*d)*(fsv/fc) = 0.30832797
 and confined core properties:
 b = 190.00
 d = 527.00
 d' = 13.00
 fcc (5A.2, TBDY) = 20.00
 cc (5A.5, TBDY) = 0.002
 c = confinement factor = 1.00
 1 = Asl,ten/(b*d)*(fs1/fc) = 0.48456674
 2 = Asl,com/(b*d)*(fs2/fc) = 0.23008205
 v = Asl,mid/(b*d)*(fsv/fc) = 0.42878928
 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 not satisfied
 --->
 Case/Assumption Rejected.
 --->
 New Case/Assumption: Unconfined full section - Spalling of concrete cover
 ' satisfies Eq. (4.4)
 --->
 v < s,y1 - LHS eq.(4.7) is not satisfied
 --->
 v < vc,y1 - RHS eq.(4.6) is satisfied
 --->
 cu (4.10) = 0.35203969
 MRc (4.17) = 6.2207E+008
 --->
 New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
 In expressions below, the following modifications have been made
 - b, d, d' replaced by geometric parameters of the core: bo, do, d'o
 - N, 1, 2, v normalised to bo*do, instead of b*d
 - - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
 --->
 Subcase: Rupture of tension steel
 --->
 v* < v*s,y2 - LHS eq.(4.5) is not satisfied

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

--->
Subcase rejected

--->
New Subcase: Failure of compression zone

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

--->
v* < v*c,y1 - RHS eq.(4.6) is satisfied

--->
*cu (4.10) = 0.4588808

MRO (4.17) = 5.3907E+008

--->
u = cu (4.2) = 8.2702663E-006

Mu = MRO

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

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

u = 6.8293729E-005

Mu = 6.6013E+008

with full section properties:

b = 600.00

d = 557.00

d' = 43.00

v = 0.00132912

N = 8883.864

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.0056977

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

From (5.4b), TBDY: cu = 0.0056977

we (5.4c) = 0.00301868

ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.15755901

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 = 71100.00 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) = 0.00229911

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) = 0.00229911

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) = 0.00229911

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 210.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

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

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

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

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.06893512

2 = Asl,com/(b*d)*(fs2/fc) = 0.14518153

v = Asl,mid/(b*d)*(fsv/fc) = 0.12846999

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.0809548$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.17049571$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.1508703$$

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

--->
 μ (4.8) = 0.15877155
 $\mu_u = M/R_c$ (4.15) = 6.6013E+008
 $u = \mu$ (4.1) = 6.8293729E-005

Calculation of ratio l_b/l_d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227298.208$

Calculation of Shear Strength at edge 1, $V_{r1} = 227298.208$

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

$$V_{Co10} = 227298.208$$

$k_{nl} = 1$ (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)

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

$$M/Vd = 4.00$$

$$\mu_u = 47.14131$$

$$V_u = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 159571.364$$

where:

$V_{s1} = 159571.364$ is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 210.00$$

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

$$s/d = 0.4375$$

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

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 210.00$$

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

$$s/d = 1.05$$

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

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$

$$b_w = 250.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 227298.208$

$$V_{r2} = V_{Co2} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Co10}$$

$$V_{Co10} = 227298.208$$

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

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'

where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

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

$M/Vd = 4.00$

$M_u = 47.14134$

$V_u = 0.00016213$

$d = 0.8 \cdot h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 159571.364$

where:

$V_{s1} = 159571.364$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

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

$s/d = 0.4375$

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

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

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

$s/d = 1.05$

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

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$

$b_w = 250.00$

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, = 1.00

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou,min} > 1$)
No FRP Wrapping

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 0.00016213$
EDGE -B-
Shear Force, $V_b = -0.00016213$
BOTH EDGES
Axial Force, $F = -8883.864$
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: $As_{c,mid} = 1545.664$

Calculation of Shear Capacity ratio , $V_e/V_r = 1.93617$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 440088.681$
with
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 6.6013E+008$
 $\mu_{1+} = 5.3907E+008$, 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
 $\mu_{1-} = 6.6013E+008$, 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
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 6.6013E+008$
 $\mu_{2+} = 5.3907E+008$, 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
 $\mu_{2-} = 6.6013E+008$, 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 μ_{1+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:
 $\mu = 8.2702663E-006$
 $\mu_u = 5.3907E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00318999$

$N = 8883.864$

$f_c = 20.00$

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

Final value of μ_c : $\mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.0056977$

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

From (5.4b), TBDY: $\mu_c = 0.0056977$

$\mu_{we} (5.4c) = 0.00301868$

$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.15755901$

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.

$A_{conf,min} = 71100.00$ 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 $b_1^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 210.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

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

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_0/l_{ou,min} = l_b/l_d = 1.00$

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

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

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

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

with $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_0/l_{ou,min} = l_b/l_{b,min} = 1.00$

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

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

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

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

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_0/l_{ou,min} = l_b/l_d = 1.00$

$su_v = 0.4 * esu_{v,nominal}$ ((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 $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 555.55$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.34843568$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.16544428$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.30832797$

and confined core properties:

$b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} \text{ (5A.2, TBDY)} = 20.00$
 $cc \text{ (5A.5, TBDY)} = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.48456674$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.23008205$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.42878928$

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 not satisfied

---->
 Case/Assumption Rejected.

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

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

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

---->
 $c_u \text{ (4.10)} = 0.35203969$
 $M_{Rc} \text{ (4.17)} = 6.2207E+008$

---->
 New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
 In expressions below, the following modifications have been made

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

---->
 Subcase: Rupture of tension steel

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

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

---->
 Subcase rejected

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

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

---->
 $v^* < v^*_{c,y1}$ - RHS eq.(4.6) is satisfied

---->
 $*c_u \text{ (4.10)} = 0.4588808$
 $M_{Ro} \text{ (4.17)} = 5.3907E+008$

---->
 $u = c_u \text{ (4.2)} = 8.2702663E-006$
 $\mu = M_{Ro}$

 Calculation of ratio l_b/l_d

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

Calculation of μ_1 -

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

$$\mu = 6.8293729E-005$$

$$\mu_1 = 6.6013E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_0 \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0056977$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0056977$$

$$w_e \text{ (5.4c)} = 0.00301868$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

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

with $fs1 = fs = 555.55$

with $Es1 = Es = 200000.00$

$y2 = 0.00231479$

$sh2 = 0.008$

$ft2 = 666.66$

$fy2 = 555.55$

$su2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

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

with $fs2 = fs = 555.55$

with $Es2 = Es = 200000.00$

$yv = 0.00231479$

$shv = 0.008$

$ftv = 666.66$

$fyv = 555.55$

$suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

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

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

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

with $fsv = fs = 555.55$

with $Esv = Es = 200000.00$

$1 = Asl, ten / (b * d) * (fs1 / fc) = 0.06893512$

$2 = Asl, com / (b * d) * (fs2 / fc) = 0.14518153$

$v = Asl, mid / (b * d) * (fsv / fc) = 0.12846999$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 20.00$

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

$c =$ confinement factor = 1.00

$1 = Asl, ten / (b * d) * (fs1 / fc) = 0.0809548$

$2 = Asl, com / (b * d) * (fs2 / fc) = 0.17049571$

$v = Asl, mid / (b * d) * (fsv / fc) = 0.1508703$

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

--->

$su (4.8) = 0.15877155$

$Mu = MRc (4.15) = 6.6013E+008$

$u = su (4.1) = 6.8293729E-005$

Calculation of ratio lb/ld

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

Calculation of Mu2+

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

$$\mu = 8.2702663E-006$$

$$Mu = 5.3907E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0056977$$

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

$$\text{From (5.4b), TBDY: } cu = 0.0056977$$

$$we \text{ (5.4c)} = 0.00301868$$

$$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00229911$$

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)

$$psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou_{min} = lb/d = 1.00$$

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

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

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

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

with $f_{s1} = f_s = 555.55$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.00231479$
 $sh_2 = 0.008$
 $ft_2 = 666.66$
 $fy_2 = 555.55$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 1.00$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 555.55$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00231479$
 $sh_v = 0.008$
 $ft_v = 666.66$
 $fy_v = 555.55$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsy_v = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsy_v = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 555.55$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.34843568$
 $2 = A_{s1,com}/(b*d)*(f_{s2}/f_c) = 0.16544428$
 $v = A_{s1,mid}/(b*d)*(f_{sv}/f_c) = 0.30832797$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.48456674$
 $2 = A_{s1,com}/(b*d)*(f_{s2}/f_c) = 0.23008205$
 $v = A_{s1,mid}/(b*d)*(f_{sv}/f_c) = 0.42878928$
 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 not satisfied
 --->
 Case/Assumption Rejected.
 --->
 New Case/Assumption: Unconfined full section - Spalling of concrete cover
 ' satisfies Eq. (4.4)
 --->
 $v < s_{y1}$ - LHS eq.(4.7) is not satisfied
 --->
 $v < v_{c,y1}$ - RHS eq.(4.6) is satisfied
 --->
 $cu (4.10) = 0.35203969$
 $MRC (4.17) = 6.2207E+008$
 --->

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

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ec

Subcase: Rupture of tension steel

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

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

Subcase rejected

New Subcase: Failure of compression zone

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

$v^* < v^*c,y1$ - RHS eq.(4.6) is satisfied

*cu (4.10) = 0.4588808

MRo (4.17) = 5.3907E+008

u = cu (4.2) = 8.2702663E-006

Mu = MRo

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

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

u = 6.8293729E-005

Mu = 6.6013E+008

with full section properties:

b = 600.00

d = 557.00

d' = 43.00

v = 0.00132912

N = 8883.864

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.0056977

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

From (5.4b), TBDY: cu = 0.0056977

we (5.4c) = 0.00301868

ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.15755901

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 = 71100.00 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) = 0.00229911

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)

$$\text{psh}_x \text{ ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00229911$$

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

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

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

$$\text{psh}_y \text{ ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00229911$$

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

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

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

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

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

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.

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

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

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

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

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.

$$\text{with } fs_2 = fs = 555.55$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

$$fy_v = 555.55$$

$$su_v = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

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

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.

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

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

$$1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.06893512$$

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.14518153$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.12846999$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 20.00$$

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

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.0809548$$

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.17049571$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.1508703$$

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

--->

$$s_u (4.8) = 0.15877155$$

$$M_u = M_{Rc} (4.15) = 6.6013E+008$$

$$u = s_u (4.1) = 6.8293729E-005$$

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227298.208$

Calculation of Shear Strength at edge 1, $V_{r1} = 227298.208$

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

$$V_{CoI0} = 227298.208$$

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

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)

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

$$M/Vd = 4.00$$

$$M_u = 47.13723$$

$$V_u = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 159571.364$$

where:

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

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 210.00$$

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

$$s/d = 1.05$$

$V_{s2} = 159571.364$ is calculated for section flange, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 210.00$$

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

$$s/d = 0.4375$$

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 356502.845$$

bw = 250.00

Calculation of Shear Strength at edge 2, $Vr2 = 227298.208$
 $Vr2 = VCol$ ((10.3), ASCE 41-17) = $knl * VCol0$
 $VCol0 = 227298.208$
 $knl = 1$ (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)
 $fc' = 20.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $Mu = 47.13721$
 $Vu = 0.00016213$
 $d = 0.8 * h = 480.00$
 $Nu = 8883.864$
 $Ag = 150000.00$
From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 159571.364$
where:
 $Vs1 = 0.00$ is calculated for section web, with:
 $d = 200.00$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 210.00$
 $Vs1$ is multiplied by $Col1 = 0.00$
 $s/d = 1.05$
 $Vs2 = 159571.364$ is calculated for section flange, with:
 $d = 480.00$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 210.00$
 $Vs2$ is multiplied by $Col2 = 1.00$
 $s/d = 0.4375$
 Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: $Vs + Vf \leq 356502.845$
 $bw = 250.00$

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, = 1.00
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Secondary Member: Concrete Strength, $fc = fcm = 20.00$
Existing material of Secondary Member: Steel Strength, $fs = fsm = 444.44$
Concrete Elasticity, $Ec = 21019.039$
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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/l_d > 1$)

No FRP Wrapping

Stepwise Properties

Bending Moment, $M = -8.4841E+006$

Shear Force, $V2 = -2791.209$

Shear Force, $V3 = 96.12431$

Axial Force, $F = -9391.552$

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, $DbL = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = u = 0.01131209$

$u = y + p = 0.01131209$

- Calculation of y -

$y = (My * L_s / 3) / E_{eff} = 0.01131209$ ((4.29), Biskinis Phd)

$My = 4.6805E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3039.571

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1921E+013$

factor = 0.30

$A_g = 237500.00$

$f_c' = 20.00$

$N = 9391.552$

$E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

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

$y_{ten} = 6.4707158E-006$

with $f_y = 444.44$

$d = 557.00$

$y = 0.3834396$

$A = 0.02975153$

$B = 0.01913377$

with $pt = 0.01254381$

$pc = 0.00595605$

$pv = 0.01109992$

$N = 9391.552$

$b = 250.00$

" = 0.07719928

$y_{comp} = 8.0247450E-006$

with $f_c = 20.00$

$E_c = 21019.039$

$y = 0.38318033$

$A = 0.02940289$

B = 0.01898202
with Es = 200000.00

Calculation of ratio l_b/l_d

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

- Calculation of ρ -

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

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$
shear control ratio $V_y E / V_{Co} I_{OE} = 1.93617$

$d = 557.00$

$s = 0.00$

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

$A_v = 78.53982$, 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.

$N_{UD} = 9391.552$

$A_g = 237500.00$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_{cE} = 20.00$

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

At local axis: 3

Integration Section: (a)

Calculation No. 5

column C1, Floor 1

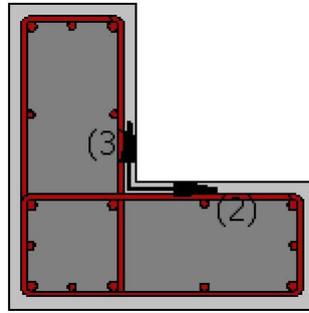
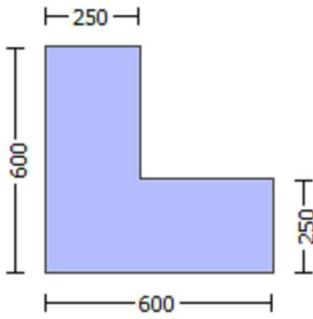
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

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: rclcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

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

#####

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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou,min} = l_b/d >= 1$)

No FRP Wrapping

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -8.4841E+006$

Shear Force, $V_a = -2791.209$

EDGE -B-

Bending Moment, $M_b = 107614.564$

Shear Force, $V_b = 2791.209$

BOTH EDGES

Axial Force, $F = -9391.552$

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, $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = V_n = 265054.139$

V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoI} = 265054.139$

$V_{CoI} = 265054.139$

$k_n = 1.00$

$displacement_ductility_demand = 0.02801895$

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)

$f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 107614.564$

$V_u = 2791.209$

$d = 0.8 \cdot h = 480.00$

$N_u = 9391.552$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 143615.664$

where:

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

$d = 200.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 210.00$

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

$s/d = 1.05$

$V_{s2} = 143615.664$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 210.00$

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

$s/d = 0.4375$

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

From (11-11), ACI 440: $V_s + V_f \leq 318865.838$

$b_w = 250.00$

$displacement_ductility_demand$ is calculated as ϕ / y

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

From analysis, chord rotation $\theta = 3.1282657E-005$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00111648$ ((4.29), Biskinis Phd)

$M_y = 4.6805E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00

From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 4.1921E+013$

$factor = 0.30$

$A_g = 237500.00$

$f_c' = 20.00$

$N = 9391.552$

$E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of ϕ / y and M_y according to Annex 7 -

y = Min(y_ten, y_com)
y_ten = 6.4707158E-006
with fy = 444.44
d = 557.00
y = 0.3834396
A = 0.02975153
B = 0.01913377
with pt = 0.01254381
pc = 0.00595605
pv = 0.01109992
N = 9391.552
b = 250.00
" = 0.07719928
y_comp = 8.0247450E-006
with fc = 20.00
Ec = 21019.039
y = 0.38318033
A = 0.02940289
B = 0.01898202
with Es = 200000.00

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

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

Calculation No. 6

column C1, Floor 1

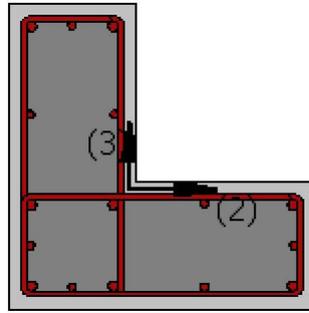
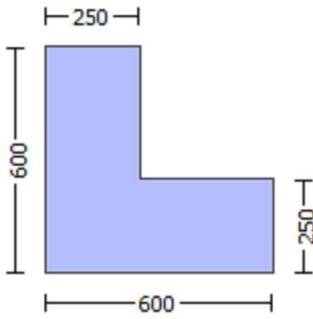
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (u)

Edge: End

Local Axis: (2)



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

At Shear local axis: 3
 (Bending local axis: 2)
 Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$

 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

 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, $L = 3000.00$

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

Stepwise Properties

At local axis: 3
 EDGE -A-
 Shear Force, $V_a = 0.00016213$
 EDGE -B-
 Shear Force, $V_b = -0.00016213$
 BOTH EDGES
 Axial Force, $F = -8883.864$
 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: $A_{sl,mid} = 1545.664$

Calculation of Shear Capacity ratio , $V_e/V_r = 1.93617$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 440088.681$

with
 $M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 6.6013E+008$
 $M_{u1+} = 5.3907E+008$, 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
 $M_{u1-} = 6.6013E+008$, 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
 $M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 6.6013E+008$
 $M_{u2+} = 5.3907E+008$, 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
 $M_{u2-} = 6.6013E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 8.2702663E-006$

$M_u = 5.3907E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$\nu = 0.00318999$

$N = 8883.864$

$f_c = 20.00$

ω (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0056977$

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

From (5.4b), TBDY: $\phi_u = 0.0056977$

ω_e (5.4c) = 0.00301868

$\omega_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.15755901$

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.

$A_{conf,min} = 71100.00$ 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).

$\phi_{sh,min} = \text{Min}(\phi_{sh,x} , \phi_{sh,y}) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$\phi_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 210.00$

$f_{ywe} = 555.55$

fce = 20.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

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

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

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

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

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

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.34843568

2 = Asl,com/(b*d)*(fs2/fc) = 0.16544428

v = Asl,mid/(b*d)*(fsv/fc) = 0.30832797

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.48456674

2 = Asl,com/(b*d)*(fs2/fc) = 0.23008205

v = Asl,mid/(b*d)*(fsv/fc) = 0.42878928

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 not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < vs,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.35203969
MRc (4.17) = 6.2207E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is satisfied
---->
*cu (4.10) = 0.4588808
MRo (4.17) = 5.3907E+008
---->
u = cu (4.2) = 8.2702663E-006
Mu = MRo

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 6.8293729E-005
Mu = 6.6013E+008

with full section properties:
b = 600.00
d = 557.00
d' = 43.00
v = 0.00132912
N = 8883.864
fc = 20.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.0056977

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

From (5.4b), TBDY: $c_u = 0.0056977$

w_e (5.4c) = 0.00301868

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$

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.

$A_{conf,min} = 71100.00$ 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 210.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

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

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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

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

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

with $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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

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

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

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$shv = 0.008$
 $ftv = 666.66$
 $fyv = 555.55$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 1.00$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv , shv,ftv,fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1,ft1,fy1$, are also multiplied by $Min(1,1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 555.55$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.06893512$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.14518153$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.12846999$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.0809548$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.17049571$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.1508703$
 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
 --->
 $su (4.8) = 0.15877155$
 $Mu = MRc (4.15) = 6.6013E+008$
 $u = su (4.1) = 6.8293729E-005$

 Calculation of ratio lb/ld

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

Calculation of Mu_{2+}

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

$u = 8.2702663E-006$
 $Mu = 5.3907E+008$

with full section properties:

$b = 250.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.0031899$
 $N = 8883.864$
 $fc = 20.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = shear_factor * Max(cu, cc) = 0.0056977$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.0056977$
 $we (5.4c) = 0.00301868$

$$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00229911$$

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)

$$psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$$psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

c = confinement factor = 1.00

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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 $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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

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

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

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

$$fy_v = 555.55$$

```

suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 1.00
suv = 0.4*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 = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.34843568
2 = Asl,com/(b*d)*(fs2/fc) = 0.16544428
v = Asl,mid/(b*d)*(fsv/fc) = 0.30832797
and confined core properties:
b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 20.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.48456674
2 = Asl,com/(b*d)*(fs2/fc) = 0.23008205
v = Asl,mid/(b*d)*(fsv/fc) = 0.42878928
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 not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
'satisfies Eq. (4.4)
---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.35203969
MRc (4.17) = 6.2207E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is satisfied
---->
*cu (4.10) = 0.4588808
MRo (4.17) = 5.3907E+008

```

--->

$$u = cu(4.2) = 8.2702663E-006$$

$$\mu = M_{Ro}$$

Calculation of ratio l_b/l_d

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

Calculation of μ_2 -

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

$$u = 6.8293729E-005$$

$$\mu = 6.6013E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0056977$$

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

$$\text{From (5.4b), TBDY: } cu = 0.0056977$$

$$w_e(5.4c) = 0.00301868$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$$

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)

$$p_{sh,x}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$p_{sh,y}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

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

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.06893512

2 = Asl,com/(b*d)*(fs2/fc) = 0.14518153

v = Asl,mid/(b*d)*(fsv/fc) = 0.12846999

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.0809548

2 = Asl,com/(b*d)*(fs2/fc) = 0.17049571

v = Asl,mid/(b*d)*(fsv/fc) = 0.1508703

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) = 0.15877155

Mu = MRc (4.15) = 6.6013E+008

u = su (4.1) = 6.8293729E-005

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227298.208$

Calculation of Shear Strength at edge 1, $V_{r1} = 227298.208$

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

$V_{Col0} = 227298.208$

$k_n l = 1$ (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)

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

$M/Vd = 4.00$

$M_u = 47.14131$

$V_u = 0.00016213$

$d = 0.8 * h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 159571.364$

where:

$V_{s1} = 159571.364$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

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

$s/d = 0.4375$

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

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

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

$s/d = 1.05$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 0.00$

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 227298.208$

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

$V_{Col0} = 227298.208$

$k_n l = 1$ (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)

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

$M/Vd = 4.00$

$M_u = 47.14134$

$V_u = 0.00016213$

$d = 0.8 * h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 159571.364$

where:

$V_{s1} = 159571.364$ is calculated for section web, with:

d = 480.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs1 is multiplied by Col1 = 1.00
s/d = 0.4375
Vs2 = 0.00 is calculated for section flange, with:
d = 200.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs2 is multiplied by Col2 = 0.00
s/d = 1.05
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 356502.845
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, = 1.00
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00
Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44
Concrete Elasticity, Ec = 21019.039
Steel Elasticity, Es = 200000.00

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, fs = 1.25*fsm = 555.55

Max Height, Hmax = 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
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length (lo/ou,min>=1)
No FRP Wrapping

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, Va = 0.00016213
EDGE -B-
Shear Force, Vb = -0.00016213
BOTH EDGES

Axial Force, $F = -8883.864$
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: $As_{mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.93617$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 440088.681$
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 6.6013E+008$
 $\mu_{1+} = 5.3907E+008$, 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
 $\mu_{1-} = 6.6013E+008$, 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
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 6.6013E+008$
 $\mu_{2+} = 5.3907E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{2-} = 6.6013E+008$, 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 μ_{1+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:
 $\mu_u = 8.2702663E-006$
 $\mu_u = 5.3907E+008$

with full section properties:

$b = 250.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.0031899$
 $N = 8883.864$
 $f_c = 20.00$
 $\omega (5A.5, \text{TBDY}) = 0.002$
Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \omega) = 0.0056977$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\mu_u = 0.0056977$
 $\omega_e (5.4c) = 0.00301868$
 $\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.15755901$
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.
 $A_{conf,min} = 71100.00$ 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).
 $\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.00229911$
Expression ((5.4d), TBDY) for $\mu_{psh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

 $\mu_{psh,x} ((5.4d), \text{TBDY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$
 L_{stir} (Length of stirrups along Y) = 1460.00
 A_{stir} (stirrups area) = 78.53982

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00229911

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 210.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y2, sh2,ft2,fy2, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.34843568

2 = Asl,com/(b*d)*(fs2/fc) = 0.16544428

v = Asl,mid/(b*d)*(fsv/fc) = 0.30832797

and confined core properties:

b = 190.00

d = 527.00

```

d' = 13.00
fcc (5A.2, TBDY) = 20.00
cc (5A.5, TBDY) = 0.002
  c = confinement factor = 1.00
  1 = Asl,ten/(b*d)*(fs1/fc) = 0.48456674
  2 = Asl,com/(b*d)*(fs2/fc) = 0.23008205
  v = Asl,mid/(b*d)*(fsv/fc) = 0.42878928
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 not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
  cu (4.10) = 0.35203969
MRC (4.17) = 6.2207E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is satisfied
---->
  *cu (4.10) = 0.4588808
MRo (4.17) = 5.3907E+008
---->
  u = cu (4.2) = 8.2702663E-006
Mu = MRo

```

Calculation of ratio lb/l_d

Adequate Lap Length: lb/l_d >= 1

Calculation of Mu1-

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

u = 6.8293729E-005

Mu = 6.6013E+008

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \alpha: \alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.0056977$$

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

$$\text{From (5.4b), TBDY: } \alpha_c = 0.0056977$$

$$\alpha_{se} (5.4c) = 0.00301868$$

$$\alpha_{se} = \text{Max}(((\alpha_{conf,max} - \alpha_{noconf}) / \alpha_{conf,max}) * (\alpha_{conf,min} / \alpha_{conf,max}), 0) = 0.15755901$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$\alpha_{conf,max} = 169100.00$ 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.

$\alpha_{conf,min} = 71100.00$ is the confined core area at midway between the levels of hoops and

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

equal to half the clear spacing between hoops.

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

$$\alpha_{psh,min} = \text{Min}(\alpha_{psh,x}, \alpha_{psh,y}) = 0.00229911$$

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

$$\alpha_{psh,x} ((5.4d), \text{TBDY}) = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00229911$$

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

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

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

$$\alpha_{psh,y} ((5.4d), \text{TBDY}) = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00229911$$

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

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

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

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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

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

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

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

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

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

$$s_u = 0.4 * e_{s2_nominal} ((5.5), TBDY) = 0.032$$

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_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.

$$\text{with } f_{s2} = f_s = 555.55$$

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

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

$$fy_v = 555.55$$

$$s_u = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

$$s_u = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$$

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 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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

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

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.06893512$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.14518153$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.12846999$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 20.00$$

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

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.0809548$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.17049571$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.1508703$$

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

--->

$$s_u (4.8) = 0.15877155$$

$$\mu_u = M_{Rc} (4.15) = 6.6013E+008$$

$$u = s_u (4.1) = 6.8293729E-005$$

Calculation of ratio l_b/l_d

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

Calculation of μ_{u2+}

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

$$u = 8.2702663E-006$$

$$\mu_u = 5.3907E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0056977$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0056977$$

$$w_e (5.4c) = 0.00301868$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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

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

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

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

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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

For calculation of $es_{u2_nominal}$ and y_2 , $sh_{2,ft2, fy2}$, it is considered characteristic value $fs_{y2} = fs_2/1.2$, from table 5.1, TBDY.

y_1 , $sh_{1,ft1, fy1}$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$s_{uv} = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

$s_{uv} = 0.4 \cdot es_{uv_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,

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

For calculation of $es_{uv_nominal}$ and y_v , sh_v, ft_v, fy_v , it is considered characteristic value $fs_{yv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1 , $sh_{1,ft1, fy1}$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = fs = 555.55$

with $Es_v = Es = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.34843568$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.16544428$

$v = As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.30832797$

and confined core properties:

$b = 190.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 20.00$

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

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

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.48456674$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.23008205$

$v = As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.42878928$

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 not satisfied

Case/Assumption Rejected.

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

' satisfies Eq. (4.4)

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

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

$cu (4.10) = 0.35203969$

$M_{Rc} (4.17) = 6.2207E+008$

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

In expressions below, the following modifications have been made

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

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

- parameters of confined concrete, f_{cc} , cc , used in lieu of f_c , ec_u

Subcase: Rupture of tension steel

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

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

Subcase rejected

--->
New Subcase: Failure of compression zone

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

--->
 $v^* < v^*c,y1$ - RHS eq.(4.6) is satisfied

--->
 $*cu$ (4.10) = 0.4588808
MRo (4.17) = 5.3907E+008

--->
 $u = cu$ (4.2) = 8.2702663E-006
Mu = MRo

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Mu2-

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

$u = 6.8293729E-005$
Mu = 6.6013E+008

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00132912$
 $N = 8883.864$

$fc = 20.00$

co (5A.5, TBDY) = 0.002

Final value of cu : $cu^* = shear_factor * Max(cu, cc) = 0.0056977$

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

From (5.4b), TBDY: $cu = 0.0056977$

we (5.4c) = 0.00301868

$ase = Max(((Aconf,max - AnoConf)/Aconf,max) * (Aconf,min/Aconf,max), 0) = 0.15755901$

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.

$Aconf,min = 71100.00$ 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).

$psh,min = Min(psh,x, psh,y) = 0.00229911$

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) = $Lstir * Astir / (Asec * s) = 0.00229911$

$Lstir$ (Length of stirrups along Y) = 1460.00

$Astir$ (stirrups area) = 78.53982

$Asec$ (section area) = 237500.00

 psh,y ((5.4d), TBDY) = $Lstir * Astir / (Asec * s) = 0.00229911$

$Lstir$ (Length of stirrups along X) = 1460.00

$Astir$ (stirrups area) = 78.53982

$Asec$ (section area) = 237500.00

 $s = 210.00$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 1.00$$

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

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

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

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

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

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

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_{b,min} = 1.00$$

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

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

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

y_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.

$$\text{with } fs_2 = fs = 555.55$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

$$fy_v = 555.55$$

$$su_v = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 1.00$$

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

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

considering characteristic value $fsy_v = fsv/1.2$, 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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

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

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

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.06893512$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.14518153$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.12846999$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 20.00$$

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

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

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.0809548$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.17049571$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.1508703$$

Case/Assumption: Unconfinedsd 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

---->

μ_u (4.8) = 0.15877155

$\mu_u = M/R_c$ (4.15) = 6.6013E+008

$u = \mu_u$ (4.1) = 6.8293729E-005

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227298.208$

Calculation of Shear Strength at edge 1, $V_{r1} = 227298.208$

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

$V_{Col0} = 227298.208$

$k_n l = 1$ (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)

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

$M/Vd = 4.00$

$\mu_u = 47.13723$

$V_u = 0.00016213$

$d = 0.8 * h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 159571.364$

where:

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

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

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

$s/d = 1.05$

$V_{s2} = 159571.364$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

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

$s/d = 0.4375$

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

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 227298.208$

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

$V_{Col0} = 227298.208$

$k_n l = 1$ (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)

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

M/Vd = 4.00
Mu = 47.13721
Vu = 0.00016213
d = 0.8*h = 480.00
Nu = 8883.864
Ag = 150000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 159571.364
where:
Vs1 = 0.00 is calculated for section web, with:
d = 200.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs1 is multiplied by Col1 = 0.00
s/d = 1.05
Vs2 = 159571.364 is calculated for section flange, with:
d = 480.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs2 is multiplied by Col2 = 1.00
s/d = 0.4375
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 356502.845
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, = 1.00
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00
Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44
Concrete Elasticity, Ec = 21019.039
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
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length (lb/lD >= 1)
No FRP Wrapping

Stepwise Properties

Bending Moment, M = -79153.178
Shear Force, V2 = 2791.209

Shear Force, $V_3 = -96.12431$
Axial Force, $F = -9391.552$
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: $A_{s,mid} = 1545.664$
Mean Diameter of Tension Reinforcement, $DbL = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = u = 0.00306454$
 $u = y + p = 0.00306454$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00306454$ ((4.29), Biskinis Phd)
 $M_y = 4.6805E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 823.446
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1921E+013$
factor = 0.30
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9391.552$
 $E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 6.4707158E-006$
with $f_y = 444.44$
 $d = 557.00$
 $y = 0.3834396$
 $A = 0.02975153$
 $B = 0.01913377$
with $pt = 0.01254381$
 $pc = 0.00595605$
 $pv = 0.01109992$
 $N = 9391.552$
 $b = 250.00$
 $" = 0.07719928$
 $y_{comp} = 8.0247450E-006$
with $f_c = 20.00$
 $E_c = 21019.039$
 $y = 0.38318033$
 $A = 0.02940289$
 $B = 0.01898202$
with $E_s = 200000.00$

Calculation of ratio l_b / l_d

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

- Calculation of p -

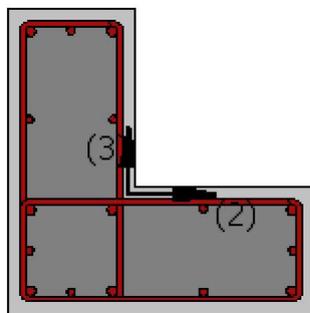
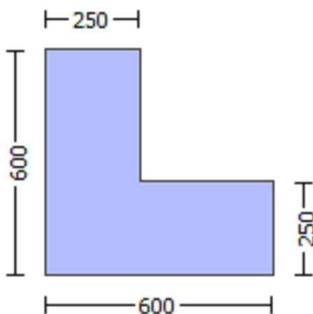
From table 10-8: $p = 0.00$
with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$
shear control ratio $V_{yE}/V_{CoIE} = 1.93617$
 $d = 557.00$
 $s = 0.00$
 $t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.00$
 $A_v = 78.53982$, 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.
 $NUD = 9391.552$
 $A_g = 237500.00$
 $f_{cE} = 20.00$
 $f_{tE} = f_{yE} = 0.00$
 $pl = Area_{Tot_Long_Rein}/(b*d) = 0.02959978$
 $b = 250.00$
 $d = 557.00$
 $f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1
At local axis: 2
Integration Section: (b)

Calculation No. 7

column C1, Floor 1
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)
Analysis: Uniform +X
Check: Shear capacity V_{Rd}
Edge: End
Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1
At local axis: 3
Integration Section: (b)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

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

#####

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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

No FRP Wrapping

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -208162.641$

Shear Force, $V_a = 96.12431$

EDGE -B-

Bending Moment, $M_b = -79153.178$

Shear Force, $V_b = -96.12431$

BOTH EDGES

Axial Force, $F = -9391.552$

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, $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 265054.139$

V_n ((10.3), ASCE 41-17) = $k_n \phi V_{Col} = 265054.139$

$V_{Col} = 265054.139$

$k_n = 1.00$

$displacement_ductility_demand = 7.0530691E-006$

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

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

$f'_c = 16.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$
 $\mu_u = 79153.178$
 $V_u = 96.12431$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 9391.552$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 143615.664$
 where:
 $V_{s1} = 143615.664$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 210.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.4375$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 210.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.05$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
 From (11-11), ACI 440: $V_s + V_f \leq 318865.838$
 $b_w = 250.00$

 displacement ductility demand is calculated as ϕ / y

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

 From analysis, chord rotation $\theta = 2.1614432E-008$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00306454$ ((4.29), Biskinis Phd)
 $M_y = 4.6805E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 823.446
 From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 4.1921E+013$
 $factor = 0.30$
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9391.552$
 $E_c \cdot I_g = 1.3974E+014$

 Calculation of Yielding Moment M_y

 Calculation of ϕ / y and M_y according to Annex 7 -

 $y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 6.4707158E-006$
 with $f_y = 444.44$
 $d = 557.00$
 $y = 0.3834396$
 $A = 0.02975153$
 $B = 0.01913377$
 with $pt = 0.01254381$
 $pc = 0.00595605$
 $pv = 0.01109992$
 $N = 9391.552$
 $b = 250.00$
 $\theta = 0.07719928$
 $y_{comp} = 8.0247450E-006$
 with $f_c = 20.00$
 $E_c = 21019.039$
 $y = 0.38318033$

A = 0.02940289
B = 0.01898202
with Es = 200000.00

Calculation of ratio I_b/I_d

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

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

At local axis: 3

Integration Section: (b)

Calculation No. 8

column C1, Floor 1

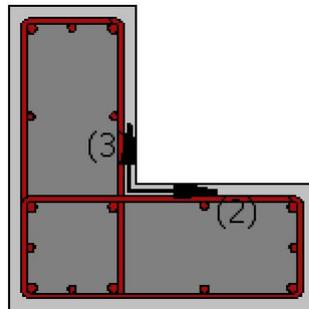
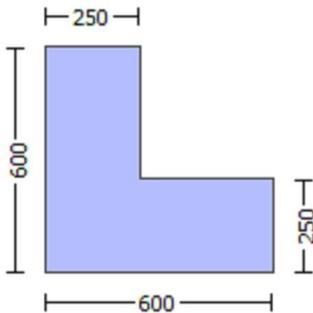
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

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, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

#####

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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou,min} > 1$)

No FRP Wrapping

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 0.00016213$

EDGE -B-

Shear Force, $V_b = -0.00016213$

BOTH EDGES

Axial Force, $F = -8883.864$

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 , $V_e/V_r = 1.93617$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 440088.681$

with

$M_{pr1} = \text{Max}(\mu_{1+} , \mu_{1-}) = 6.6013E+008$

$\mu_{1+} = 5.3907E+008$, 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

$\mu_{1-} = 6.6013E+008$, 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

$M_{pr2} = \text{Max}(\mu_{2+} , \mu_{2-}) = 6.6013E+008$

$\mu_{2+} = 5.3907E+008$, 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

$\mu_{2-} = 6.6013E+008$, 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 μ_{1+}

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

$\mu = 8.2702663E-006$

$M_u = 5.3907E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0056977$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0056977$$

$$w_e (5.4c) = 0.00301868$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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

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

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

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

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

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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

For calculation of $es_{u2_nominal}$ and y_2 , $sh_{2,ft2,fy2}$, it is considered characteristic value $fs_{y2} = fs_2/1.2$, from table 5.1, TBDY.

y_1 , $sh_{1,ft1,fy1}$, are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$s_{uv} = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

$s_{uv} = 0.4 \cdot es_{uv_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,

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

For calculation of $es_{uv_nominal}$ and y_v , sh_v, ft_v, fy_v , it is considered characteristic value $fs_{yv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1 , $sh_{1,ft1,fy1}$, are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = fs = 555.55$

with $Es_v = Es = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.34843568$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.16544428$

$v = As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.30832797$

and confined core properties:

$b = 190.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 20.00$

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

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

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.48456674$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.23008205$

$v = As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.42878928$

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 not satisfied

Case/Assumption Rejected.

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

' satisfies Eq. (4.4)

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

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

$cu (4.10) = 0.35203969$

$M_{Rc} (4.17) = 6.2207E+008$

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

In expressions below, the following modifications have been made

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

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

- parameters of confined concrete, f_{cc} , cc , used in lieu of f_c , ecu

Subcase: Rupture of tension steel

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

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

Subcase rejected

--->
New Subcase: Failure of compression zone

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

--->
 $v^* < v^*c,y1$ - RHS eq.(4.6) is satisfied

--->
 $*cu$ (4.10) = 0.4588808
MRo (4.17) = 5.3907E+008

--->
 $u = cu$ (4.2) = 8.2702663E-006
Mu = MRo

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld \geq 1

Calculation of Mu1-

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

$u = 6.8293729E-005$
Mu = 6.6013E+008

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00132912$
 $N = 8883.864$
 $fc = 20.00$
 co (5A.5, TBDY) = 0.002
Final value of cu : $cu^* = shear_factor * Max(cu, cc) = 0.0056977$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $cu = 0.0056977$

we (5.4c) = 0.00301868
 $ase = Max(((Aconf,max - AnoConf)/Aconf,max) * (Aconf,min/Aconf,max), 0) = 0.15755901$
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.
 $Aconf,min = 71100.00$ 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).
 $psh,min = Min(psh,x, psh,y) = 0.00229911$
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) = $Lstir * Astir / (Asec * s) = 0.00229911$
 $Lstir$ (Length of stirrups along Y) = 1460.00
 $Astir$ (stirrups area) = 78.53982
 $Asec$ (section area) = 237500.00

 psh,y ((5.4d), TBDY) = $Lstir * Astir / (Asec * s) = 0.00229911$
 $Lstir$ (Length of stirrups along X) = 1460.00
 $Astir$ (stirrups area) = 78.53982
 $Asec$ (section area) = 237500.00

 $s = 210.00$

$$fywe = 555.55$$

$$fce = 20.00$$

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

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

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

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

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

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

$$y2 = 0.00231479$$

$$sh2 = 0.008$$

$$ft2 = 666.66$$

$$fy2 = 555.55$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

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

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

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

$$yv = 0.00231479$$

$$shv = 0.008$$

$$ftv = 666.66$$

$$fyv = 555.55$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

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

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

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

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.06893512$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.14518153$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.12846999$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 20.00$$

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

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0809548$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.17049571$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.1508703$$

Case/Assumption: Unconfinedsd full section - Steel rupture

satisfies Eq. (4.3)

---->

$v < v_s, y_2$ - LHS eq.(4.5) is not satisfied

---->

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

---->

s_u (4.8) = 0.15877155

$M_u = M_{Rc}$ (4.15) = 6.6013E+008

$u = s_u$ (4.1) = 6.8293729E-005

Calculation of ratio l_b/l_d

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

Calculation of M_{u2+}

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

$u = 8.2702663E-006$

$M_u = 5.3907E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

ω (5A.5, TBDY) = 0.002

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0056977$

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

From (5.4b), TBDY: $c_u = 0.0056977$

w_e (5.4c) = 0.00301868

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$

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.

$A_{conf,min} = 71100.00$ 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 210.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

$c = \text{confinement factor} = 1.00$
 $y1 = 0.00231479$
 $sh1 = 0.008$
 $ft1 = 666.66$
 $fy1 = 555.55$
 $su1 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \text{min} = lb/ld = 1.00$
 $su1 = 0.4 * esu1_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu1_nominal = 0.08$,
 For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
 characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs1 = fs = 555.55$
 with $Es1 = Es = 200000.00$
 $y2 = 0.00231479$
 $sh2 = 0.008$
 $ft2 = 666.66$
 $fy2 = 555.55$
 $su2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \text{min} = lb/lb, \text{min} = 1.00$
 $su2 = 0.4 * esu2_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs2 = fs = 555.55$
 with $Es2 = Es = 200000.00$
 $yv = 0.00231479$
 $shv = 0.008$
 $ftv = 666.66$
 $fyv = 555.55$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \text{min} = lb/ld = 1.00$
 $suv = 0.4 * esuv_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 555.55$
 with $Esv = Es = 200000.00$
 $1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.34843568$
 $2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.16544428$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.30832797$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, \text{TBDY}) = 20.00$
 $cc (5A.5, \text{TBDY}) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.48456674$
 $2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.23008205$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.42878928$
 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 not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.35203969
MRc (4.17) = 6.2207E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is satisfied
---->
*cu (4.10) = 0.4588808
MRo (4.17) = 5.3907E+008
---->
u = cu (4.2) = 8.2702663E-006
Mu = MRo

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 6.8293729E-005
Mu = 6.6013E+008

with full section properties:
b = 600.00
d = 557.00
d' = 43.00
v = 0.00132912
N = 8883.864
fc = 20.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.0056977
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.0056977

$$w_e (5.4c) = 0.00301868$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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.

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

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

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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.

$$\text{with } fs_2 = fs = 555.55$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

$$f_{yv} = 555.55$$

$$s_{uv} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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 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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

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

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

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.06893512$$

$$2 = A_{s1,com}/(b*d)*(f_{s2}/f_c) = 0.14518153$$

$$v = A_{s1,mid}/(b*d)*(f_{sv}/f_c) = 0.12846999$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 20.00$$

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

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

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.0809548$$

$$2 = A_{s1,com}/(b*d)*(f_{s2}/f_c) = 0.17049571$$

$$v = A_{s1,mid}/(b*d)*(f_{sv}/f_c) = 0.1508703$$

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

--->

$$s_u (4.8) = 0.15877155$$

$$\mu = M_{Rc} (4.15) = 6.6013E+008$$

$$u = s_u (4.1) = 6.8293729E-005$$

Calculation of ratio l_b/l_d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227298.208$

Calculation of Shear Strength at edge 1, $V_{r1} = 227298.208$

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

$$V_{Co10} = 227298.208$$

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

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

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

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

$$M/Vd = 4.00$$

$$\mu = 47.14131$$

$$V_u = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 159571.364$$

where:

$V_{s1} = 159571.364$ is calculated for section web, with:

d = 480.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs1 is multiplied by Col1 = 1.00
s/d = 0.4375
Vs2 = 0.00 is calculated for section flange, with:
d = 200.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs2 is multiplied by Col2 = 0.00
s/d = 1.05
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 356502.845
bw = 250.00

Calculation of Shear Strength at edge 2, Vr2 = 227298.208
Vr2 = VCol ((10.3), ASCE 41-17) = knl*VCol0
VCol0 = 227298.208
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' = 20.00, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 47.14134
Vu = 0.00016213
d = 0.8*h = 480.00
Nu = 8883.864
Ag = 150000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 159571.364
where:
Vs1 = 159571.364 is calculated for section web, with:
d = 480.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs1 is multiplied by Col1 = 1.00
s/d = 0.4375
Vs2 = 0.00 is calculated for section flange, with:
d = 200.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs2 is multiplied by Col2 = 0.00
s/d = 1.05
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 356502.845
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: rdcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

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, $L = 3000.00$
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou, min} > 1$)
No FRP Wrapping

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 0.00016213$
EDGE -B-
Shear Force, $V_b = -0.00016213$
BOTH EDGES
Axial Force, $F = -8883.864$
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, $V_e/V_r = 1.93617$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 440088.681$
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 6.6013E+008$
 $M_{u1+} = 5.3907E+008$, 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
 $M_{u1-} = 6.6013E+008$, 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
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 6.6013E+008$
 $M_{u2+} = 5.3907E+008$, 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
 $M_{u2-} = 6.6013E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 8.2702663E-006$$

$$\mu = 5.3907E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00318999$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0056977$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.0056977$$

$$\phi_{ue} \text{ (5.4c)} = 0.00301868$$

$$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00229911$$

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)

$$\phi_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$\phi_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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

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.

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

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

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$ft2 = 666.66$
 $fy2 = 555.55$
 $su2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/lb,min = 1.00$
 $su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2,ft2,fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1,ft1,fy1$, are also multiplied by $Min(1,1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs2 = fs = 555.55$
 with $Es2 = Es = 200000.00$
 $yv = 0.00231479$
 $shv = 0.008$
 $ftv = 666.66$
 $fyv = 555.55$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/d = 1.00$
 $suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv,ftv,fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1,ft1,fy1$, are also multiplied by $Min(1,1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 555.55$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.34843568$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.16544428$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.30832797$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.48456674$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.23008205$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.42878928$
 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 not satisfied
 --->
 Case/Assumption Rejected.
 --->
 New Case/Assumption: Unconfined full section - Spalling of concrete cover
 ' satisfies Eq. (4.4)
 --->
 $v < s,y1$ - LHS eq.(4.7) is not satisfied
 --->
 $v < vc,y1$ - RHS eq.(4.6) is satisfied
 --->
 $cu (4.10) = 0.35203969$
 $MRC (4.17) = 6.2207E+008$
 --->
 New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
 In expressions below, the following modifications have been made
 - b, d, d' replaced by geometric parameters of the core: $bo, do, d'o$
 - $N, 1, 2, v$ normalised to $bo*do$, instead of $b*d$

- - parameters of confined concrete, f_{cc} , c_c , used in lieu of f_c , e_{cu}

---->

Subcase: Rupture of tension steel

---->

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

---->

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

---->

Subcase rejected

---->

New Subcase: Failure of compression zone

---->

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

---->

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

---->

$*c_u$ (4.10) = 0.4588808

M_{Ro} (4.17) = 5.3907E+008

---->

$u = c_u$ (4.2) = 8.2702663E-006

$\mu = M_{Ro}$

Calculation of ratio l_b/d

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

Calculation of μ_{u1} -

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

$u = 6.8293729E-005$

$\mu_u = 6.6013E+008$

with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00132912$

$N = 8883.864$

$f_c = 20.00$

ω (5A.5, TBDY) = 0.002

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0056977$

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

From (5.4b), TBDY: $c_u = 0.0056977$

w_e (5.4c) = 0.00301868

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$

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.

$A_{conf,min} = 71100.00$ 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

L_{stir} (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) = 0.00229911
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 210.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.002
c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

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

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

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

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.06893512

2 = Asl,com/(b*d)*(fs2/fc) = 0.14518153

v = Asl,mid/(b*d)*(fsv/fc) = 0.12846999

and confined core properties:

b = 540.00

$d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.0809548$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.17049571$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.1508703$
 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
 --->

$s_u (4.8) = 0.15877155$
 $\mu_u = MR_c (4.15) = 6.6013E+008$
 $u = s_u (4.1) = 6.8293729E-005$

 Calculation of ratio l_b/d

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

 Calculation of μ_{u2+}

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 8.2702663E-006$
 $\mu_u = 5.3907E+008$

with full section properties:

$b = 250.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.0031899$
 $N = 8883.864$
 $f_c = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, cc) = 0.0056977$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $c_u = 0.0056977$
 we (5.4c) = 0.00301868

$ase = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.15755901$
 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.
 $A_{conf,min} = 71100.00$ 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).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$
 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)

 $p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$
 L_{stir} (Length of stirrups along Y) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

$$\text{psh,y ((5.4d), TBDY)} = \text{Lstir} \cdot \text{Astir} / (\text{Asec} \cdot \text{s}) = 0.00229911$$

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

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

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

$$\text{s} = 210.00$$

$$\text{fywe} = 555.55$$

$$\text{fce} = 20.00$$

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

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

$$\text{y1} = 0.00231479$$

$$\text{sh1} = 0.008$$

$$\text{ft1} = 666.66$$

$$\text{fy1} = 555.55$$

$$\text{su1} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/ld} = 1.00$$

$$\text{su1} = 0.4 \cdot \text{esu1_nominal ((5.5), TBDY)} = 0.032$$

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 $\text{Min}(1, 1.25 \cdot (\text{lb/ld})^{2/3})$, from 10.3.5, ASCE41-17.

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

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

$$\text{y2} = 0.00231479$$

$$\text{sh2} = 0.008$$

$$\text{ft2} = 666.66$$

$$\text{fy2} = 555.55$$

$$\text{su2} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/lb,min} = 1.00$$

$$\text{su2} = 0.4 \cdot \text{esu2_nominal ((5.5), TBDY)} = 0.032$$

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 $\text{Min}(1, 1.25 \cdot (\text{lb/ld})^{2/3})$, from 10.3.5, ASCE41-17.

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

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

$$\text{yv} = 0.00231479$$

$$\text{shv} = 0.008$$

$$\text{ftv} = 666.66$$

$$\text{fyv} = 555.55$$

$$\text{su} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/ld} = 1.00$$

$$\text{su} = 0.4 \cdot \text{esuv_nominal ((5.5), TBDY)} = 0.032$$

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 $\text{Min}(1, 1.25 \cdot (\text{lb/ld})^{2/3})$, from 10.3.5, ASCE41-17.

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

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

$$1 = \text{Asl,ten} / (\text{b} \cdot \text{d}) \cdot (\text{fs1} / \text{fc}) = 0.34843568$$

$$2 = \text{Asl,com} / (\text{b} \cdot \text{d}) \cdot (\text{fs2} / \text{fc}) = 0.16544428$$

$$\text{v} = \text{Asl,mid} / (\text{b} \cdot \text{d}) \cdot (\text{fsv} / \text{fc}) = 0.30832797$$

and confined core properties:

$$\text{b} = 190.00$$

$$\text{d} = 527.00$$

$$\text{d}' = 13.00$$

$$\text{fcc (5A.2, TBDY)} = 20.00$$

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.48456674

2 = Asl,com/(b*d)*(fs2/fc) = 0.23008205

v = Asl,mid/(b*d)*(fsv/fc) = 0.42878928

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 not satisfied

---->
Case/Assumption Rejected.

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

---->
v < s,y1 - LHS eq.(4.7) is not satisfied

---->
v < vc,y1 - RHS eq.(4.6) is satisfied

---->
cu (4.10) = 0.35203969
MRc (4.17) = 6.2207E+008

---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu

---->
Subcase: Rupture of tension steel

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

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

---->
Subcase rejected

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

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

---->
v* < v*c,y1 - RHS eq.(4.6) is satisfied

---->
*cu (4.10) = 0.4588808
MRo (4.17) = 5.3907E+008

---->
u = cu (4.2) = 8.2702663E-006
Mu = MRo

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 6.8293729E-005
Mu = 6.6013E+008

with full section properties:
b = 600.00

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$fc = 20.00$$

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

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0056977$$

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

$$\text{From (5.4b), TBDY: } cu = 0.0056977$$

$$we \text{ (5.4c)} = 0.00301868$$

$$ase = \text{Max}(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.15755901$$

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 = 71100.00 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).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00229911$$

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)

$$psh,x \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00229911$$

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

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

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

$$psh,y \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00229911$$

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

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

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

$$s = 210.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

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

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

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

$$su1 = 0.4 * esu1_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

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

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

$$y2 = 0.00231479$$

$$sh2 = 0.008$$

$$ft2 = 666.66$$

$$fy2 = 555.55$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/l_{b,min} = 1.00$$

$$su2 = 0.4 * esu2_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $es_{u2_nominal} = 0.08$,

For calculation of $es_{u2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fs_{y2} = fs_2/1.2$, from table 5.1, TBDY.

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

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$s_{uv} = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$lo/lo_{u,min} = lb/d = 1.00$

$s_{uv} = 0.4 \cdot es_{uv_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,

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

For calculation of $es_{uv_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $fs_{yv} = f_{sv}/1.2$, 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 $f_{sv} = fs = 555.55$

with $Es_v = Es = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.06893512$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.14518153$

$v = As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.12846999$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 20.00$

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

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

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0809548$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.17049571$

$v = As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.1508703$

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

--->

$s_u (4.8) = 0.15877155$

$M_u = MR_c (4.15) = 6.6013E+008$

$u = s_u (4.1) = 6.8293729E-005$

Calculation of ratio lb/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227298.208$

Calculation of Shear Strength at edge 1, $V_{r1} = 227298.208$

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

$V_{Col0} = 227298.208$

$knl = 1$ (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)

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

$M/Vd = 4.00$
 $\mu_u = 47.13723$
 $V_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 159571.364$
 where:
 $V_{s1} = 0.00$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 210.00$
 V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 1.05$
 $V_{s2} = 159571.364$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 210.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.4375$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 227298.208$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{Col0}$
 $V_{Col0} = 227298.208$
 $knl = 1$ (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)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 47.13721$
 $V_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 159571.364$
 where:
 $V_{s1} = 0.00$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 210.00$
 V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 1.05$
 $V_{s2} = 159571.364$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 210.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.4375$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

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, $\gamma = 1.00$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/l_d > 1$)

No FRP Wrapping

Stepwise Properties

Bending Moment, $M = 107614.564$

Shear Force, $V_2 = 2791.209$

Shear Force, $V_3 = -96.12431$

Axial Force, $F = -9391.552$

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, $Db_L = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \gamma \cdot u = 0.00111648$

$u = \gamma \cdot u_{,R} = 0.00111648$

- Calculation of γ -

$\gamma = (M \cdot L_s / 3) / E_{eff} = 0.00111648$ ((4.29), Biskinis Phd)

$M \gamma = 4.6805E+008$

$L_s = M / V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00

From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 4.1921E+013$

factor = 0.30

$A_g = 237500.00$

$f_c' = 20.00$

$N = 9391.552$

$E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of ρ_y and M_y according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 6.4707158\text{E-}006$
with $f_y = 444.44$
 $d = 557.00$
 $y = 0.3834396$
 $A = 0.02975153$
 $B = 0.01913377$
with $p_t = 0.01254381$
 $p_c = 0.00595605$
 $p_v = 0.01109992$
 $N = 9391.552$
 $b = 250.00$
 $\rho = 0.07719928$
 $y_{\text{comp}} = 8.0247450\text{E-}006$
with $f_c = 20.00$
 $E_c = 21019.039$
 $y = 0.38318033$
 $A = 0.02940289$
 $B = 0.01898202$
with $E_s = 200000.00$

Calculation of ratio l_b/d

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

- Calculation of ρ_p -

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

with:

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

shear control ratio $V_y E / C_o I_o E = 1.93617$

$d = 557.00$

$s = 0.00$

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

$A_v = 78.53982$, 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.

$N_{UD} = 9391.552$

$A_g = 237500.00$

$f_{cE} = 20.00$

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

$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_{cE} = 20.00$

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

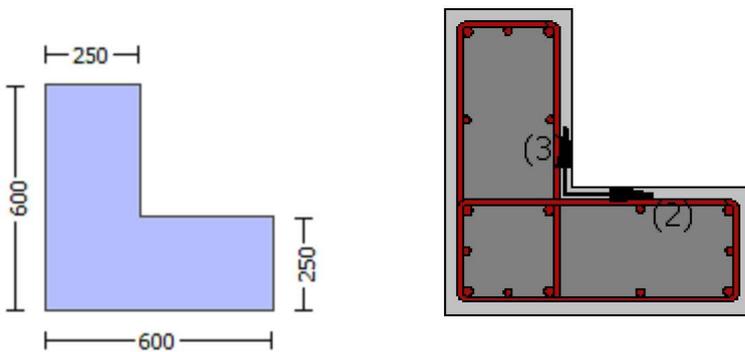
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (2)



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

At local axis: 2

Integration Section: (a)

Section Type: rdcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

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

#####

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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou,min} = l_b/l_d \geq 1$)
No FRP Wrapping

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -1.2874E+007$
Shear Force, $V_a = -4235.571$
EDGE -B-
Bending Moment, $M_b = 163326.055$
Shear Force, $V_b = 4235.571$
BOTH EDGES
Axial Force, $F = -9654.265$
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, $D_{bL,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = *V_n = 204360.764$
 $V_n ((10.3), ASCE 41-17) = knl * V_{Co10} = 204360.764$
 $V_{Co1} = 204360.764$
 $knl = 1.00$
 $displacement_ductility_demand = 0.01112676$

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)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 1.2874E+007$
 $V_u = 4235.571$
 $d = 0.8 * h = 480.00$
 $N_u = 9654.265$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 143615.664$
where:
 $V_{s1} = 0.00$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 210.00$
 V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 1.05$
 $V_{s2} = 143615.664$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 210.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.4375$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
From (11-11), ACI 440: $V_s + V_f \leq 318865.838$
 $bw = 250.00$

 $displacement_ductility_demand$ is calculated as / y

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

From analysis, chord rotation $\theta = 0.00012588$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.01131335$ ((4.29), Biskinis Phd))
 $M_y = 4.6810E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 3039.576
From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 4.1921E+013$
factor = 0.30
Ag = 237500.00
fc' = 20.00
N = 9654.265
 $E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of ϕ_y and M_y according to Annex 7 -

 $y = \text{Min}(\phi_{y_ten}, \phi_{y_com})$
 $\phi_{y_ten} = 6.4711079E-006$
with $f_y = 444.44$
d = 557.00
y = 0.38347696
A = 0.02975578
B = 0.01913802
with pt = 0.01254381
pc = 0.00595605
pv = 0.01109992
N = 9654.265
b = 250.00
" = 0.07719928
 $\phi_{y_comp} = 8.0241107E-006$
with fc = 20.00
Ec = 21019.039
y = 0.38321062
A = 0.02939738
B = 0.01898202
with Es = 200000.00

Calculation of ratio I_b/I_d

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

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

Calculation No. 10

column C1, Floor 1

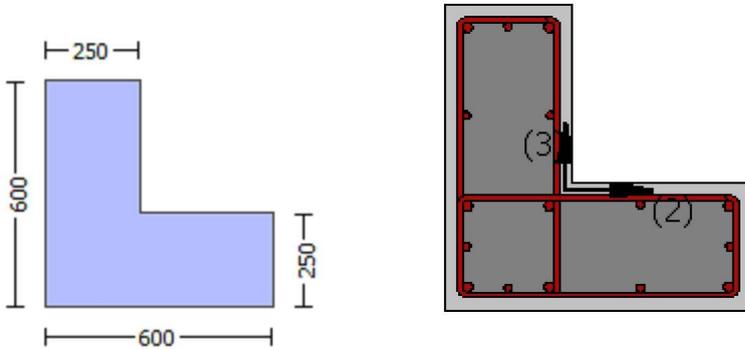
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_r)

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, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

No FRP Wrapping

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 0.00016213$
 EDGE -B-
 Shear Force, $V_b = -0.00016213$
 BOTH EDGES
 Axial Force, $F = -8883.864$
 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, $V_e/V_r = 1.93617$
 Member Controlled by Shear ($V_e/V_r > 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 440088.681$

with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 6.6013E+008$
 $M_{u1+} = 5.3907E+008$, 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
 $M_{u1-} = 6.6013E+008$, 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
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 6.6013E+008$
 $M_{u2+} = 5.3907E+008$, 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
 $M_{u2-} = 6.6013E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 8.2702663E-006$
 $M_u = 5.3907E+008$

 with full section properties:

$b = 250.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.0031899$
 $N = 8883.864$
 $f_c = 20.00$
 α_1 (5A.5, TBDY) = 0.002
 Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0056977$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\phi_u = 0.0056977$
 ω_e (5.4c) = 0.00301868
 $\alpha_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.15755901$
 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.
 $A_{conf,min} = 71100.00$ 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).
 $\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00229911$
 Expression ((5.4d), TBDY) for $\phi_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 210.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = $0.4 * esu1_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

su2 = $0.4 * esu2_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

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

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

suv = $0.4 * esuv_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

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

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = $Asl,ten / (b * d) * (fs1 / fc) = 0.34843568$

2 = $Asl,com / (b * d) * (fs2 / fc) = 0.16544428$

```

v = Asl,mid/(b*d)*(fsv/fc) = 0.30832797
and confined core properties:
b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 20.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.48456674
2 = Asl,com/(b*d)*(fs2/fc) = 0.23008205
v = Asl,mid/(b*d)*(fsv/fc) = 0.42878928
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 not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < s,y1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.35203969
MRc (4.17) = 6.2207E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
--->
v* < v*s,c - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
--->
v* < v*c,y1 - RHS eq.(4.6) is satisfied
--->
*cu (4.10) = 0.4588808
MRo (4.17) = 5.3907E+008
--->
u = cu (4.2) = 8.2702663E-006
Mu = MRo
-----

Calculation of ratio lb/lc
-----
Adequate Lap Length: lb/lc >= 1
-----
-----
Calculation of Mu1-
-----
-----

```

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

$$\mu = 6.8293729E-005$$

$$\mu_u = 6.6013E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.0056977$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.0056977$$

$$\mu_{ue} \text{ (5.4c)} = 0.00301868$$

$$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.00229911$$

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)

$$\mu_{psh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$\mu_{psh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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

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

characteristic value $fsy_1 = fs_1 / 1.2$, 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 $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

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

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

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

y_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.

$$\text{with } fs_2 = fs = 555.55$$

$$\text{with } Es_2 = Es = 200000.00$$

$$yv = 0.00231479$$

$$shv = 0.008$$

$$ftv = 666.66$$

$$fyv = 555.55$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

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

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

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

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

For calculation of $esuv_{nominal}$ and yv, shv, ftv, fyv , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

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.

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

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

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.06893512$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.14518153$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.12846999$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 20.00$$

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

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

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.0809548$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.17049571$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.1508703$$

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

---->

$$su (4.8) = 0.15877155$$

$$Mu = MRc (4.15) = 6.6013E+008$$

$$u = su (4.1) = 6.8293729E-005$$

Calculation of ratio lb/ld

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

Calculation of Mu_{2+}

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

$$u = 8.2702663E-006$$

$$Mu = 5.3907E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0056977$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0056977$$

$$w_e \text{ (5.4c)} = 0.00301868$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

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

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

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

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

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

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

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

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.

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

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

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00
 lo/lou,min = lb/lb,min = 1.00
 su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
 From table 5A.1, TBDY: esu2_nominal = 0.08,
 For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
 characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
 y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.
 with fs2 = fs = 555.55
 with Es2 = Es = 200000.00
 yv = 0.00231479
 shv = 0.008
 ftv = 666.66
 fyv = 555.55
 suv = 0.032
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 lo/lou,min = lb/d = 1.00
 suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
 From table 5A.1, TBDY: esuv_nominal = 0.08,
 considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
 For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
 characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
 y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.
 with fsv = fs = 555.55
 with Esv = Es = 200000.00
 1 = Asl,ten/(b*d)*(fs1/fc) = 0.34843568
 2 = Asl,com/(b*d)*(fs2/fc) = 0.16544428
 v = Asl,mid/(b*d)*(fsv/fc) = 0.30832797
 and confined core properties:
 b = 190.00
 d = 527.00
 d' = 13.00
 fcc (5A.2, TBDY) = 20.00
 cc (5A.5, TBDY) = 0.002
 c = confinement factor = 1.00
 1 = Asl,ten/(b*d)*(fs1/fc) = 0.48456674
 2 = Asl,com/(b*d)*(fs2/fc) = 0.23008205
 v = Asl,mid/(b*d)*(fsv/fc) = 0.42878928
 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 not satisfied
 --->
 Case/Assumption Rejected.
 --->
 New Case/Assumption: Unconfined full section - Spalling of concrete cover
 ' satisfies Eq. (4.4)
 --->
 v < s,y1 - LHS eq.(4.7) is not satisfied
 --->
 v < vc,y1 - RHS eq.(4.6) is satisfied
 --->
 cu (4.10) = 0.35203969
 MRc (4.17) = 6.2207E+008
 --->
 New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
 In expressions below, the following modifications have been made
 - b, d, d' replaced by geometric parameters of the core: bo, do, d'o
 - N, 1, 2, v normalised to bo*do, instead of b*d
 - - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
 --->
 Subcase: Rupture of tension steel
 --->
 v* < v*s,y2 - LHS eq.(4.5) is not satisfied

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

--->
Subcase rejected

--->
New Subcase: Failure of compression zone

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

--->
v* < v*c,y1 - RHS eq.(4.6) is satisfied

--->
*cu (4.10) = 0.4588808

MRO (4.17) = 5.3907E+008

--->
u = cu (4.2) = 8.2702663E-006

Mu = MRO

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

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

u = 6.8293729E-005

Mu = 6.6013E+008

with full section properties:

b = 600.00

d = 557.00

d' = 43.00

v = 0.00132912

N = 8883.864

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.0056977

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

From (5.4b), TBDY: cu = 0.0056977

we (5.4c) = 0.00301868

ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.15755901

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 = 71100.00 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) = 0.00229911

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) = 0.00229911

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) = 0.00229911

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 210.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.06893512

2 = Asl,com/(b*d)*(fs2/fc) = 0.14518153

v = Asl,mid/(b*d)*(fsv/fc) = 0.12846999

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.0809548$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.17049571$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.1508703$$

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

--->
 μ (4.8) = 0.15877155
 $\mu_u = M/R_c$ (4.15) = 6.6013E+008
 $u = \mu$ (4.1) = 6.8293729E-005

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227298.208$

Calculation of Shear Strength at edge 1, $V_{r1} = 227298.208$

$$V_{r1} = V_{Co1} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Co10}$$

$$V_{Co10} = 227298.208$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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)
 $f'_c = 20.00$, but $f_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 47.14131$
 $\nu_u = 0.00016213$
 $d = 0.8*h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 159571.364$
 where:
 $V_{s1} = 159571.364$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 210.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.4375$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 210.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.05$
 V_f ((11-3)-(11.4), ACI 440) = 0.00
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 227298.208$

$$V_{r2} = V_{Co2} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Co10}$$

$$V_{Co10} = 227298.208$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'

where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$M_u = 47.14134$

$V_u = 0.00016213$

$d = 0.8 \cdot h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 159571.364$

where:

$V_{s1} = 159571.364$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.4375$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.05$

V_f ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$

$b_w = 250.00$

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, = 1.00

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou,min} > 1$)
No FRP Wrapping

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 0.00016213$
EDGE -B-
Shear Force, $V_b = -0.00016213$
BOTH EDGES
Axial Force, $F = -8883.864$
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: $As_{,mid} = 1545.664$

Calculation of Shear Capacity ratio , $V_e/V_r = 1.93617$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 440088.681$
with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 6.6013E+008$
 $\mu_{u1+} = 5.3907E+008$, 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
 $\mu_{u1-} = 6.6013E+008$, 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
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 6.6013E+008$
 $\mu_{u2+} = 5.3907E+008$, 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
 $\mu_{u2-} = 6.6013E+008$, 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 μ_{u1+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:
 $\mu_u = 8.2702663E-006$
 $\mu_u = 5.3907E+008$

with full section properties:

$b = 250.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00318999$
 $N = 8883.864$
 $f_c = 20.00$
 $co (5A.5, TBDY) = 0.002$
Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.0056977$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\mu_u = 0.0056977$
 $\mu_u (5.4c) = 0.00301868$
 $\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$
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.

$A_{conf,min} = 71100.00$ 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 210.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.002$

$c = \text{confinement factor} = 1.00$

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$su_1 = 0.4 * esu_{1,nominal}$ ((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 $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 * esu_{2,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$su_v = 0.4 * esu_{v,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 555.55$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.34843568$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.16544428$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.30832797$

and confined core properties:

$b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 fcc (5A.2, TBDY) = 20.00
 cc (5A.5, TBDY) = 0.002
 $c =$ confinement factor = 1.00
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.48456674$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.23008205$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.42878928$

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 not satisfied

---->
 Case/Assumption Rejected.

---->
 New Case/Assumption: Unconfined full section - Spalling of concrete cover
 ' satisfies Eq. (4.4)

---->
 $v < s,y1$ - LHS eq.(4.7) is not satisfied

---->
 $v < vc,y1$ - RHS eq.(4.6) is satisfied

---->
 cu (4.10) = 0.35203969
 MRC (4.17) = 6.2207E+008

---->
 New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
 In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: $bo, do, d'o$
- $N, 1, 2, v$ normalised to $bo*do$, instead of $b*d$
- parameters of confined concrete, fcc, cc , used in lieu of fc, ecu

---->
 Subcase: Rupture of tension steel

---->
 $v^* < v^*,y2$ - LHS eq.(4.5) is not satisfied

---->
 $v^* < v^*,c$ - LHS eq.(4.5) is not satisfied

---->
 Subcase rejected

---->
 New Subcase: Failure of compression zone

---->
 $v^* < v^*,y2$ - LHS eq.(4.6) is not satisfied

---->
 $v^* < v^*,y1$ - RHS eq.(4.6) is satisfied

---->
 $*cu$ (4.10) = 0.4588808
 MRO (4.17) = 5.3907E+008

---->
 $u = cu$ (4.2) = 8.2702663E-006
 $Mu = MRO$

 Calculation of ratio lb/ld

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_1 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 6.8293729E-005$$

$$\mu_1 = 6.6013E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_0 \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0056977$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0056977$$

$$w_e \text{ (5.4c)} = 0.00301868$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

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$A_{conf,max} = 169100.00$ 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.

$A_{conf,min} = 71100.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 555.55$

with $Es1 = Es = 200000.00$

$y2 = 0.00231479$

$sh2 = 0.008$

$ft2 = 666.66$

$fy2 = 555.55$

$su2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lou, min = lb/lb, min = 1.00$

$su2 = 0.4 \cdot esu2_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 555.55$

with $Es2 = Es = 200000.00$

$yv = 0.00231479$

$shv = 0.008$

$ftv = 666.66$

$fyv = 555.55$

$suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lou, min = lb/ld = 1.00$

$suv = 0.4 \cdot esuv_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fsv = fs = 555.55$

with $Esv = Es = 200000.00$

$1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.06893512$

$2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.14518153$

$v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.12846999$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

$c =$ confinement factor = 1.00

$1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.0809548$

$2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.17049571$

$v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.1508703$

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) = 0.15877155

$Mu = MRc$ (4.15) = 6.6013E+008

$u = su$ (4.1) = 6.8293729E-005

Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of Mu2+

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 8.2702663E-006$$

$$Mu = 5.3907E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0056977$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0056977$$

$$w_e (5.4c) = 0.00301868$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

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$A_{conf,max} = 169100.00$ 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.

$A_{conf,min} = 71100.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

$$L_{stir} (\text{Length of stirrups along } Y) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

$$L_{stir} (\text{Length of stirrups along } X) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / d = 1.00$$

$$su_1 = 0.4 * esu_1_{nominal} ((5.5), TBDY) = 0.032$$

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 $\text{Min}(1, 1.25 * (l_b / d)^{2/3})$, from 10.3.5, ASCE41-17.

```

with fs1 = fs = 555.55
with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE41-17.
with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.34843568
2 = Asl,com/(b*d)*(fs2/fc) = 0.16544428
v = Asl,mid/(b*d)*(fsv/fc) = 0.30832797
and confined core properties:
b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 20.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.48456674
2 = Asl,com/(b*d)*(fs2/fc) = 0.23008205
v = Asl,mid/(b*d)*(fsv/fc) = 0.42878928
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 not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
'satisfies Eq. (4.4)
---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.35203969
MRc (4.17) = 6.2207E+008
---->

```

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ec

--->

Subcase: Rupture of tension steel

--->

$v^* < v^*s_y2$ - LHS eq.(4.5) is not satisfied

--->

$v^* < v^*s_c$ - LHS eq.(4.5) is not satisfied

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

$v^* < v^*c_y2$ - LHS eq.(4.6) is not satisfied

--->

$v^* < v^*c_y1$ - RHS eq.(4.6) is satisfied

--->

*cu (4.10) = 0.4588808

MRo (4.17) = 5.3907E+008

--->

u = cu (4.2) = 8.2702663E-006

Mu = MRo

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 6.8293729E-005

Mu = 6.6013E+008

with full section properties:

b = 600.00

d = 557.00

d' = 43.00

v = 0.00132912

N = 8883.864

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.0056977

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.0056977

we (5.4c) = 0.00301868

ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.15755901

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)

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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 = 71100.00 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) = 0.00229911

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)

$$\text{psh},x \text{ ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00229911$$

$$\text{Lstir (Length of stirrups along Y)} = 1460.00$$

$$\text{Astir (stirrups area)} = 78.53982$$

$$\text{Asec (section area)} = 237500.00$$

$$\text{psh},y \text{ ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00229911$$

$$\text{Lstir (Length of stirrups along X)} = 1460.00$$

$$\text{Astir (stirrups area)} = 78.53982$$

$$\text{Asec (section area)} = 237500.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 1.00$$

$$su1 = 0.4 * esu1_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1, ft1, fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 555.55$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00231479$$

$$sh2 = 0.008$$

$$ft2 = 666.66$$

$$fy2 = 555.55$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \text{min} = lb/lb, \text{min} = 1.00$$

$$su2 = 0.4 * esu2_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2, ft2, fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 555.55$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00231479$$

$$shv = 0.008$$

$$ftv = 666.66$$

$$fyv = 555.55$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 1.00$$

$$suv = 0.4 * esuv_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value 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.

$$\text{with } fsv = fs = 555.55$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = \text{Asl}, \text{ten} / (b * d) * (fs1 / fc) = 0.06893512$$

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.14518153$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.12846999$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 20.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.0809548$$

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.17049571$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.1508703$$

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

--->

$$s_u (4.8) = 0.15877155$$

$$M_u = M_{Rc} (4.15) = 6.6013E+008$$

$$u = s_u (4.1) = 6.8293729E-005$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227298.208$

Calculation of Shear Strength at edge 1, $V_{r1} = 227298.208$

$$V_{r1} = V_{Co10} ((10.3), ASCE 41-17) = k_{nl} * V_{Co10}$$

$$V_{Co10} = 227298.208$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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)

$$f_c' = 20.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$M_u = 47.13723$$

$$V_u = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 159571.364$$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 210.00$$

V_{s1} is multiplied by $Col1 = 0.00$

$$s/d = 1.05$$

$V_{s2} = 159571.364$ is calculated for section flange, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 210.00$$

V_{s2} is multiplied by $Col2 = 1.00$

$$s/d = 0.4375$$

$$V_f ((11-3)-(11.4), ACI 440) = 0.00$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 356502.845$$

bw = 250.00

Calculation of Shear Strength at edge 2, $Vr2 = 227298.208$
 $Vr2 = VCol$ ((10.3), ASCE 41-17) = $knl * VCol0$
 $VCol0 = 227298.208$
 $knl = 1$ (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)
 $fc' = 20.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $Mu = 47.13721$
 $Vu = 0.00016213$
 $d = 0.8 * h = 480.00$
 $Nu = 8883.864$
 $Ag = 150000.00$
From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 159571.364$
where:
 $Vs1 = 0.00$ is calculated for section web, with:
 $d = 200.00$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 210.00$
 $Vs1$ is multiplied by $Col1 = 0.00$
 $s/d = 1.05$
 $Vs2 = 159571.364$ is calculated for section flange, with:
 $d = 480.00$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 210.00$
 $Vs2$ is multiplied by $Col2 = 1.00$
 $s/d = 0.4375$
 Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: $Vs + Vf \leq 356502.845$
 $bw = 250.00$

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, = 1.00
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Secondary Member: Concrete Strength, $fc = fcm = 20.00$
Existing material of Secondary Member: Steel Strength, $fs = fsm = 444.44$
Concrete Elasticity, $Ec = 21019.039$
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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/l_d > 1$)

No FRP Wrapping

Stepwise Properties

Bending Moment, $M = -315855.763$

Shear Force, $V_2 = -4235.571$

Shear Force, $V_3 = 145.8655$

Axial Force, $F = -9654.265$

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, $DbL = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = u = 0.03663188$

$u = y + p = 0.03663188$

- Calculation of y -

$y = (My * L_s / 3) / E_{eff} = 0.00805962$ ((4.29), Biskinis Phd)

$My = 4.6810E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 2165.391

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1921E+013$

factor = 0.30

$A_g = 237500.00$

$f_c' = 20.00$

$N = 9654.265$

$E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 6.4711079E-006$

with $f_y = 444.44$

$d = 557.00$

$y = 0.38347696$

$A = 0.02975578$

$B = 0.01913802$

with $pt = 0.01254381$

$pc = 0.00595605$

$pv = 0.01109992$

$N = 9654.265$

$b = 250.00$

$" = 0.07719928$

$y_{comp} = 8.0241107E-006$

with $f_c = 20.00$

$E_c = 21019.039$

$y = 0.38321062$

$A = 0.02939738$

B = 0.01898202
with Es = 200000.00

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

- Calculation of p -

From table 10-8: p = 0.02857227

with:

- Columns controlled by inadequate development or splicing along the clear height because lb/d < 1
shear control ratio $V_y E / V_{Co} I_{OE} = 1.93617$

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 = 9654.265

$A_g = 237500.00$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 0.00$

$p_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.02959978$

b = 250.00

d = 557.00

$f_{cE} = 20.00$

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

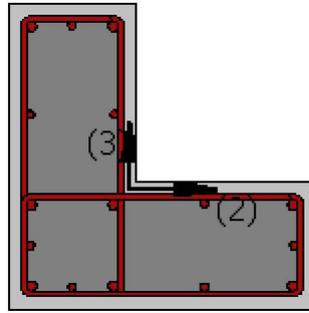
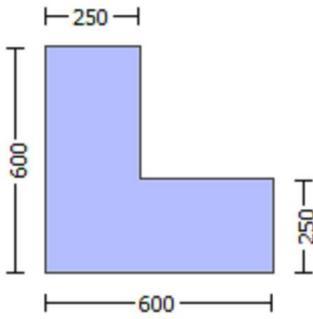
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

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: rclcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou,min} = l_b/l_d >= 1$)

No FRP Wrapping

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -315855.763$

Shear Force, $V_a = 145.8655$

EDGE -B-

Bending Moment, $M_b = -120136.814$

Shear Force, $V_b = -145.8655$

BOTH EDGES

Axial Force, $F = -9654.265$

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, $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = V_n = 204360.764$

V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoI} = 204360.764$

$V_{CoI} = 204360.764$

$k_n = 1.00$

$displacement_ductility_demand = 0.00585495$

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)

$f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 315855.763$

$V_u = 145.8655$

$d = 0.8 \cdot h = 480.00$

$N_u = 9654.265$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 143615.664$

where:

$V_{s1} = 143615.664$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 210.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.4375$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 210.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.05$

V_f ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: $V_s + V_f \leq 318865.838$

$b_w = 250.00$

$displacement_ductility_demand$ is calculated as ϕ / y

- Calculation of ϕ / y for END A -
for rotation axis 2 and integ. section (a)

From analysis, chord rotation $\theta = 4.7188645E-005$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00805962$ ((4.29), Biskinis Phd)

$M_y = 4.6810E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 2165.391

From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 4.1921E+013$

$factor = 0.30$

$A_g = 237500.00$

$f_c' = 20.00$

$N = 9654.265$

$E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of ϕ / y and M_y according to Annex 7 -

y = Min(y_ten, y_com)
y_ten = 6.4711079E-006
with fy = 444.44
d = 557.00
y = 0.38347696
A = 0.02975578
B = 0.01913802
with pt = 0.01254381
pc = 0.00595605
pv = 0.01109992
N = 9654.265
b = 250.00
" = 0.07719928
y_comp = 8.0241107E-006
with fc = 20.00
Ec = 21019.039
y = 0.38321062
A = 0.02939738
B = 0.01898202
with Es = 200000.00

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

End Of Calculation of Shear Capacity for element: column LC1 of floor 1
At local axis: 3
Integration Section: (a)

Calculation No. 12

column C1, Floor 1

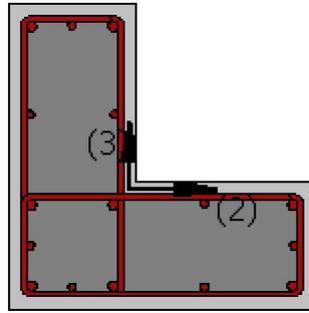
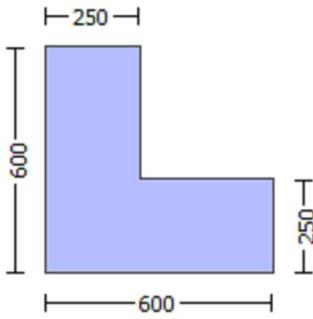
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

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, $\gamma = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$

 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

 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, $L = 3000.00$

Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{ou, min} >= 1$)
 No FRP Wrapping

Stepwise Properties

At local axis: 3
 EDGE -A-
 Shear Force, $V_a = 0.00016213$
 EDGE -B-
 Shear Force, $V_b = -0.00016213$
 BOTH EDGES
 Axial Force, $F = -8883.864$
 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 , $V_e/V_r = 1.93617$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 440088.681$

with

$M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 6.6013E+008$

$M_{u1+} = 5.3907E+008$, 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

$M_{u1-} = 6.6013E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 6.6013E+008$

$M_{u2+} = 5.3907E+008$, 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

$M_{u2-} = 6.6013E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 8.2702663E-006$

$M_u = 5.3907E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$\nu = 0.00318999$

$N = 8883.864$

$f_c = 20.00$

ω (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0056977$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.0056977$

ω_e (5.4c) = 0.00301868

$\omega_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.15755901$

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.

$A_{conf,min} = 71100.00$ 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).

$\rho_{sh,min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.00229911$

Expression ((5.4d), TBDY) for $\rho_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\rho_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$\rho_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 210.00$

$f_{ywe} = 555.55$

fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{d})^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{d})^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered

characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{d})^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.34843568

2 = Asl,com/(b*d)*(fs2/fc) = 0.16544428

v = Asl,mid/(b*d)*(fsv/fc) = 0.30832797

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.48456674

2 = Asl,com/(b*d)*(fs2/fc) = 0.23008205

v = Asl,mid/(b*d)*(fsv/fc) = 0.42878928

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 not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < vs,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.35203969
MRc (4.17) = 6.2207E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is satisfied
---->
*cu (4.10) = 0.4588808
MRo (4.17) = 5.3907E+008
---->
u = cu (4.2) = 8.2702663E-006
Mu = MRo

```

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 6.8293729E-005$

$M_u = 6.6013E+008$

with full section properties:

b = 600.00

d = 557.00

d' = 43.00

v = 0.00132912

N = 8883.864

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0056977$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.0056977$

w_e (5.4c) = 0.00301868

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$

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.

$A_{conf,min} = 71100.00$ 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 210.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.002$

$c = \text{confinement factor} = 1.00$

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$su_1 = 0.4 * esu1_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 * esu2_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and y_2 , sh_2 , ft_2 , fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2 , sh_2 , ft_2 , fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$shv = 0.008$
 $ftv = 666.66$
 $fyv = 555.55$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 1.00$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv , shv,ftv,fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1,ft1,fy1$, are also multiplied by $Min(1,1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 555.55$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.06893512$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.14518153$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.12846999$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.0809548$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.17049571$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.1508703$
 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
 --->
 $su (4.8) = 0.15877155$
 $Mu = MRc (4.15) = 6.6013E+008$
 $u = su (4.1) = 6.8293729E-005$

 Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of Mu_{2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 8.2702663E-006$
 $Mu = 5.3907E+008$

with full section properties:

$b = 250.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.0031899$
 $N = 8883.864$
 $fc = 20.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = shear_factor * Max(cu, cc) = 0.0056977$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.0056977$
 $we (5.4c) = 0.00301868$

$$ase = \text{Max}(((Aconf,max - AnoConf) / Aconf,max) * (Aconf,min / Aconf,max), 0) = 0.15755901$$

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 = 71100.00 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).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00229911$$

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)

$$psh,x \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00229911$$

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

$$psh,y \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00229911$$

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

$$s = 210.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

From ((5.A5), TBDY), TBDY: $cc = 0.002$

$c = \text{confinement factor} = 1.00$

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/l_d = 1.00$$

$$su1 = 0.4 * esu1_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 555.55$

with $Es1 = Es = 200000.00$

$$y2 = 0.00231479$$

$$sh2 = 0.008$$

$$ft2 = 666.66$$

$$fy2 = 555.55$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/l_b,min = 1.00$$

$$su2 = 0.4 * esu2_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 555.55$

with $Es2 = Es = 200000.00$

$$yv = 0.00231479$$

$$shv = 0.008$$

$$ftv = 666.66$$

$$fyv = 555.55$$

```

suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.34843568
2 = Asl,com/(b*d)*(fs2/fc) = 0.16544428
v = Asl,mid/(b*d)*(fsv/fc) = 0.30832797
and confined core properties:
b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 20.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.48456674
2 = Asl,com/(b*d)*(fs2/fc) = 0.23008205
v = Asl,mid/(b*d)*(fsv/fc) = 0.42878928
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 not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
'satisfies Eq. (4.4)
---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.35203969
MRc (4.17) = 6.2207E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is satisfied
---->
*cu (4.10) = 0.4588808
MRo (4.17) = 5.3907E+008

```

--->

$$u = cu(4.2) = 8.2702663E-006$$

$$\mu = M_{Ro}$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_2

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$u = 6.8293729E-005$$

$$\mu = 6.6013E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0056977$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.0056977$$

$$w_e(5.4c) = 0.00301868$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

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$A_{conf,max} = 169100.00$ 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.

$A_{conf,min} = 71100.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$$

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)

$$p_{sh,x}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.06893512

2 = Asl,com/(b*d)*(fs2/fc) = 0.14518153

v = Asl,mid/(b*d)*(fsv/fc) = 0.12846999

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.0809548

2 = Asl,com/(b*d)*(fs2/fc) = 0.17049571

v = Asl,mid/(b*d)*(fsv/fc) = 0.1508703

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) = 0.15877155

Mu = MRc (4.15) = 6.6013E+008

u = su (4.1) = 6.8293729E-005

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227298.208$

Calculation of Shear Strength at edge 1, $V_{r1} = 227298.208$

$V_{r1} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_n l * V_{\text{Col}0}$

$V_{\text{Col}0} = 227298.208$

$k_n l = 1$ (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)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 47.14131$

$V_u = 0.00016213$

$d = 0.8 * h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 159571.364$

where:

$V_{s1} = 159571.364$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

V_{s1} is multiplied by $\text{Col}1 = 1.00$

$s/d = 0.4375$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

V_{s2} is multiplied by $\text{Col}2 = 0.00$

$s/d = 1.05$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 0.00$

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 227298.208$

$V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_n l * V_{\text{Col}0}$

$V_{\text{Col}0} = 227298.208$

$k_n l = 1$ (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)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 47.14134$

$V_u = 0.00016213$

$d = 0.8 * h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 159571.364$

where:

$V_{s1} = 159571.364$ is calculated for section web, with:

d = 480.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs1 is multiplied by Col1 = 1.00
s/d = 0.4375
Vs2 = 0.00 is calculated for section flange, with:
d = 200.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs2 is multiplied by Col2 = 0.00
s/d = 1.05
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 356502.845
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, = 1.00
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00
Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44
Concrete Elasticity, Ec = 21019.039
Steel Elasticity, Es = 200000.00

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, fs = 1.25*fsm = 555.55

Max Height, Hmax = 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
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length (lo/ou,min>=1)
No FRP Wrapping

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, Va = 0.00016213
EDGE -B-
Shear Force, Vb = -0.00016213
BOTH EDGES

Axial Force, $F = -8883.864$
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: $As_{,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.93617$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 440088.681$
with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 6.6013E+008$
 $Mu_{1+} = 5.3907E+008$, 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
 $Mu_{1-} = 6.6013E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 6.6013E+008$
 $Mu_{2+} = 5.3907E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination
 $Mu_{2-} = 6.6013E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 8.2702663E-006$
 $M_u = 5.3907E+008$

with full section properties:

$b = 250.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.0031899$
 $N = 8883.864$
 $f_c = 20.00$
 $\omega (5A.5, \text{TBDY}) = 0.002$
Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0056977$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_u = 0.0056977$
 $\phi_w (5.4c) = 0.00301868$
 $\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.15755901$
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.
 $A_{conf,min} = 71100.00$ 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).
 $\phi_{psh,min} = \text{Min}(\phi_{psh,x}, \phi_{psh,y}) = 0.00229911$
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)

 $\phi_{psh,x} ((5.4d), \text{TBDY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$
 L_{stir} (Length of stirrups along Y) = 1460.00
 A_{stir} (stirrups area) = 78.53982

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00229911

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 210.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y2, sh2,ft2,fy2, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

su_v = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su_v = 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 = 555.55

with Es_v = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.34843568

2 = Asl,com/(b*d)*(fs2/fc) = 0.16544428

v = Asl,mid/(b*d)*(fsv/fc) = 0.30832797

and confined core properties:

b = 190.00

d = 527.00

```

d' = 13.00
fcc (5A.2, TBDY) = 20.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.48456674
2 = Asl,com/(b*d)*(fs2/fc) = 0.23008205
v = Asl,mid/(b*d)*(fsv/fc) = 0.42878928
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 not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.35203969
MRc (4.17) = 6.2207E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is satisfied
---->
*cu (4.10) = 0.4588808
MRo (4.17) = 5.3907E+008
---->
u = cu (4.2) = 8.2702663E-006
Mu = MRo
-----

Calculation of ratio lb/d
-----

Adequate Lap Length: lb/d >= 1
-----
-----

Calculation of Mu1-
-----
-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 6.8293729E-005
Mu = 6.6013E+008
-----

```

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$\alpha (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \alpha: \alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.0056977$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \alpha_c = 0.0056977$$

$$\alpha_{se} (5.4c) = 0.00301868$$

$$\alpha_{se} = \text{Max}(((\alpha_{conf,max} - \alpha_{noconf}) / \alpha_{conf,max}) * (\alpha_{conf,min} / \alpha_{conf,max}), 0) = 0.15755901$$

The definitions of α_{noconf} , $\alpha_{conf,min}$ and $\alpha_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$\alpha_{conf,max} = 169100.00$ 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.

$\alpha_{conf,min} = 71100.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $\alpha_{conf,max}$ by a length

equal to half the clear spacing between hoops.

$\alpha_{noconf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$\alpha_{psh,min} = \text{Min}(\alpha_{psh,x}, \alpha_{psh,y}) = 0.00229911$$

Expression ((5.4d), TBDY) for $\alpha_{psh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\alpha_{psh,x} ((5.4d), \text{TBDY}) = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00229911$$

$$\text{Lstir (Length of stirrups along Y)} = 1460.00$$

$$\text{Astir (stirrups area)} = 78.53982$$

$$\text{Asec (section area)} = 237500.00$$

$$\alpha_{psh,y} ((5.4d), \text{TBDY}) = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00229911$$

$$\text{Lstir (Length of stirrups along X)} = 1460.00$$

$$\text{Astir (stirrups area)} = 78.53982$$

$$\text{Asec (section area)} = 237500.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \alpha_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{1,nominal} = 0.08,$$

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 555.55$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$$

$$s_u = 0.4 * e_{s2_nominal} ((5.5), TBDY) = 0.032$$

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_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.

$$\text{with } f_{s2} = f_s = 555.55$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

$$fy_v = 555.55$$

$$s_u = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 1.00$$

$$s_u = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$$

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 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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{sv} = f_s = 555.55$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.06893512$$

$$2 = A_{s1,com}/(b*d)*(f_{s2}/f_c) = 0.14518153$$

$$v = A_{s1,mid}/(b*d)*(f_{sv}/f_c) = 0.12846999$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 20.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.0809548$$

$$2 = A_{s1,com}/(b*d)*(f_{s2}/f_c) = 0.17049571$$

$$v = A_{s1,mid}/(b*d)*(f_{sv}/f_c) = 0.1508703$$

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

--->

$$s_u (4.8) = 0.15877155$$

$$\mu_u = M_{Rc} (4.15) = 6.6013E+008$$

$$u = s_u (4.1) = 6.8293729E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of μ_{u2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 8.2702663E-006$$

$$\mu_u = 5.3907E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0056977$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0056977$$

$$w_e (5.4c) = 0.00301868$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

$$L_{stir} (\text{Length of stirrups along X}) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu1_{nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_{nominal} = 0.08,$$

For calculation of $esu1_{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fs_1 = fs_1/1.2$, 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.

$$\text{with } fs_1 = fs = 555.55$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$$

$$su_2 = 0.4 * esu2_{nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_{nominal} = 0.08,$$

For calculation of $es_{u2_nominal}$ and y_2 , $sh_{2,ft2,fy2}$, it is considered characteristic value $fs_{y2} = fs_2/1.2$, from table 5.1, TBDY.

y_1 , $sh_{1,ft1,fy1}$, are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$s_{uv} = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$s_{uv} = 0.4 \cdot es_{uv_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,

considering characteristic value $fs_{yv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $es_{uv_nominal}$ and y_v , sh_v, ft_v, fy_v , it is considered characteristic value $fs_{yv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1 , $sh_{1,ft1,fy1}$, are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = fs = 555.55$

with $Es_v = Es = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.34843568$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.16544428$

$v = As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.30832797$

and confined core properties:

$b = 190.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 20.00$

$cc (5A.5, TBDY) = 0.002$

$c = \text{confinement factor} = 1.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.48456674$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.23008205$

$v = As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.42878928$

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 not satisfied

Case/Assumption Rejected.

New Case/Assumption: Unconfined full section - Spalling of concrete cover

' satisfies Eq. (4.4)

$v < s_{y1}$ - LHS eq.(4.7) is not satisfied

$v < v_{c,y1}$ - RHS eq.(4.6) is satisfied

$cu (4.10) = 0.35203969$

$M_{Rc} (4.17) = 6.2207E+008$

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- b , d , d' replaced by geometric parameters of the core: b_o , d_o , d'_o

- N , 1, 2, v normalised to $b_o \cdot d_o$, instead of $b \cdot d$

- parameters of confined concrete, f_{cc} , cc , used in lieu of f_c , ecu

Subcase: Rupture of tension steel

$v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

$v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

Subcase rejected

--->
New Subcase: Failure of compression zone

--->
 $v^* < v^*c,y2$ - LHS eq.(4.6) is not satisfied

--->
 $v^* < v^*c,y1$ - RHS eq.(4.6) is satisfied

--->
 $*cu$ (4.10) = 0.4588808
MRo (4.17) = 5.3907E+008

--->
 $u = cu$ (4.2) = 8.2702663E-006
Mu = MRo

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld \geq 1

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 6.8293729E-005$
Mu = 6.6013E+008

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00132912$
 $N = 8883.864$

$fc = 20.00$

co (5A.5, TBDY) = 0.002

Final value of cu : $cu^* = shear_factor * Max(cu, cc) = 0.0056977$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.0056977$

we (5.4c) = 0.00301868

$ase = Max(((Aconf,max - AnoConf)/Aconf,max) * (Aconf,min/Aconf,max), 0) = 0.15755901$

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.

$Aconf,min = 71100.00$ 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).

$psh,min = Min(psh,x, psh,y) = 0.00229911$

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) = $Lstir * Astir / (Asec * s) = 0.00229911$

$Lstir$ (Length of stirrups along Y) = 1460.00

$Astir$ (stirrups area) = 78.53982

$Asec$ (section area) = 237500.00

 psh,y ((5.4d), TBDY) = $Lstir * Astir / (Asec * s) = 0.00229911$

$Lstir$ (Length of stirrups along X) = 1460.00

$Astir$ (stirrups area) = 78.53982

$Asec$ (section area) = 237500.00

 $s = 210.00$

$$fywe = 555.55$$

$$fce = 20.00$$

From (5A.5), TBDY), TBDY: $cc = 0.002$

$$c = \text{confinement factor} = 1.00$$

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 1.00$$

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and $y1$, $sh1$, $ft1$, $fy1$, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1$, $sh1$, $ft1$, $fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 555.55$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00231479$$

$$sh2 = 0.008$$

$$ft2 = 666.66$$

$$fy2 = 555.55$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 1.00$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2$, $sh2$, $ft2$, $fy2$, it is considered
characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1$, $sh1$, $ft1$, $fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 555.55$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00231479$$

$$shv = 0.008$$

$$ftv = 666.66$$

$$fyv = 555.55$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 1.00$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_nominal$ and yv , shv , ftv , fyv , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1$, $sh1$, $ft1$, $fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 555.55$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.06893512$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.14518153$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.12846999$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 20.00$$

$$cc (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0809548$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.17049571$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.1508703$$

Case/Assumption: Unconfinedsd 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

---->

μ_u (4.8) = 0.15877155

$\mu_u = M/R_c$ (4.15) = 6.6013E+008

$u = \mu_u$ (4.1) = 6.8293729E-005

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227298.208$

Calculation of Shear Strength at edge 1, $V_{r1} = 227298.208$

$V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l^* V_{Col0}$

$V_{Col0} = 227298.208$

$k_n l = 1$ (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)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/V_d = 4.00$

$\mu_u = 47.13723$

$V_u = 0.00016213$

$d = 0.8 * h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 159571.364$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 1.05$

$V_{s2} = 159571.364$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

V_{s2} is multiplied by $Col2 = 1.00$

$s/d = 0.4375$

V_f ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 227298.208$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l^* V_{Col0}$

$V_{Col0} = 227298.208$

$k_n l = 1$ (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)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00
Mu = 47.13721
Vu = 0.00016213
d = 0.8*h = 480.00
Nu = 8883.864
Ag = 150000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 159571.364
where:
Vs1 = 0.00 is calculated for section web, with:
d = 200.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs1 is multiplied by Col1 = 0.00
s/d = 1.05
Vs2 = 159571.364 is calculated for section flange, with:
d = 480.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs2 is multiplied by Col2 = 1.00
s/d = 0.4375
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 356502.845
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, = 1.00
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00
Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44
Concrete Elasticity, Ec = 21019.039
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
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length (lb/lD >= 1)
No FRP Wrapping

Stepwise Properties

Bending Moment, M = -1.2874E+007
Shear Force, V2 = -4235.571

Shear Force, $V_3 = 145.8655$
Axial Force, $F = -9654.265$
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, $DbL = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \rho \cdot u = 0.03988561$
 $u = \rho \cdot y + p = 0.03988561$

- Calculation of y -

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.01131335$ ((4.29), Biskinis Phd)
 $M_y = 4.6810E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 3039.576
From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 4.1921E+013$
factor = 0.30
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9654.265$
 $E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 6.4711079E-006$
with $f_y = 444.44$
 $d = 557.00$
 $y = 0.38347696$
 $A = 0.02975578$
 $B = 0.01913802$
with $pt = 0.01254381$
 $pc = 0.00595605$
 $pv = 0.01109992$
 $N = 9654.265$
 $b = 250.00$
 $\rho = 0.07719928$
 $y_{comp} = 8.0241107E-006$
with $f_c = 20.00$
 $E_c = 21019.039$
 $y = 0.38321062$
 $A = 0.02939738$
 $B = 0.01898202$
with $E_s = 200000.00$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

- Calculation of p -

From table 10-8: $p = 0.02857227$
with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$
shear control ratio $V_{yE}/V_{ColOE} = 1.93617$

$d = 557.00$

$s = 0.00$

$$t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.00$$

$A_v = 78.53982$, 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.

$NUD = 9654.265$

$A_g = 237500.00$

$f_{cE} = 20.00$

$f_{tE} = f_{yE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein}/(b*d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_{cE} = 20.00$

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

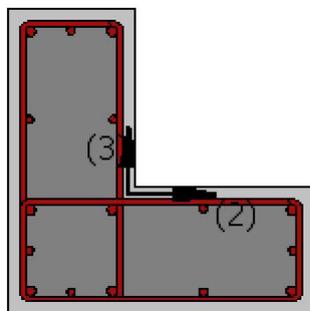
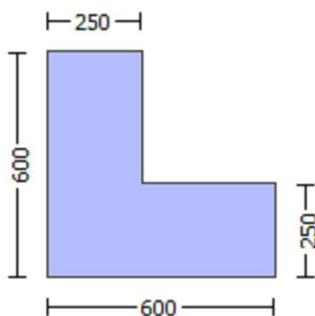
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

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: rclcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou,min} = l_b/l_d >= 1$)

No FRP Wrapping

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -1.2874E+007$

Shear Force, $V_a = -4235.571$

EDGE -B-

Bending Moment, $M_b = 163326.055$

Shear Force, $V_b = 4235.571$

BOTH EDGES

Axial Force, $F = -9654.265$

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: $A_{sl,mid} = 1545.664$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 265105.864$

V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoI} = 265105.864$

$V_{CoI} = 265105.864$

$k_n = 1.00$

$displacement_ductility_demand = 0.04250475$

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ $\phi \cdot V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$\phi = 1$ (normal-weight concrete)

$f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$
 $\mu_u = 163326.055$
 $V_u = 4235.571$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 9654.265$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 143615.664$
 where:
 $V_{s1} = 0.00$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 210.00$
 V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 1.05$
 $V_{s2} = 143615.664$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 210.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.4375$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
 From (11-11), ACI 440: $V_s + V_f \leq 318865.838$
 $b_w = 250.00$

 displacement ductility demand is calculated as ϕ / y

- Calculation of ϕ / y for END B -
 for rotation axis 3 and integ. section (b)

 From analysis, chord rotation $\theta = 4.7460989E-005$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.0011166$ ((4.29), Biskinis Phd))
 $M_y = 4.6810E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00
 From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 4.1921E+013$
 $factor = 0.30$
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9654.265$
 $E_c \cdot I_g = 1.3974E+014$

 Calculation of Yielding Moment M_y

 Calculation of ϕ / y and M_y according to Annex 7 -

 $y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 6.4711079E-006$
 with $f_y = 444.44$
 $d = 557.00$
 $y = 0.38347696$
 $A = 0.02975578$
 $B = 0.01913802$
 with $pt = 0.01254381$
 $pc = 0.00595605$
 $pv = 0.01109992$
 $N = 9654.265$
 $b = 250.00$
 $\theta = 0.07719928$
 $y_{comp} = 8.0241107E-006$
 with $f_c = 20.00$
 $E_c = 21019.039$
 $y = 0.38321062$

A = 0.02939738
B = 0.01898202
with Es = 200000.00

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 14

column C1, Floor 1

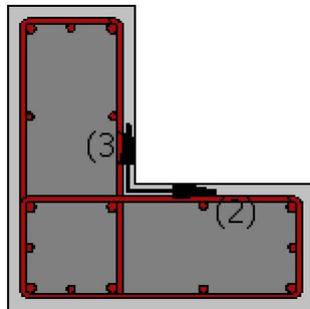
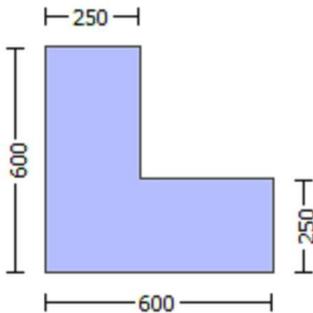
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (u)

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rdcs

Constant Properties

Knowledge Factor, = 1.00

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou,min} > 1$)

No FRP Wrapping

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 0.00016213$

EDGE -B-

Shear Force, $V_b = -0.00016213$

BOTH EDGES

Axial Force, $F = -8883.864$

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, $V_e/V_r = 1.93617$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 440088.681$

with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 6.6013E+008$

$\mu_{1+} = 5.3907E+008$, 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

$\mu_{1-} = 6.6013E+008$, 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 6.6013E+008$

$\mu_{2+} = 5.3907E+008$, 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

$\mu_{2-} = 6.6013E+008$, 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 μ_{1+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 8.2702663E-006$

$M_u = 5.3907E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

d' = 43.00

v = 0.0031899

N = 8883.864

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.0056977

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.0056977

we (5.4c) = 0.00301868

ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.15755901

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 = 71100.00 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) = 0.00229911

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) = 0.00229911

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) = 0.00229911

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 210.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^{2/3}), from 10.3.5, ASCE41-17.

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of $es_{u2_nominal}$ and y_2 , sh_2, ft_2, fy_2 , it is considered characteristic value $fs_{y2} = fs_2/1.2$, from table 5.1, TBDY.

y_1 , sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$s_{uv} = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{u,min} = lb/d = 1.00$

$s_{uv} = 0.4 \cdot es_{uv_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,

considering characteristic value $fs_{yv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $es_{uv_nominal}$ and y_v , sh_v, ft_v, fy_v , it is considered characteristic value $fs_{yv} = f_{sv}/1.2$, 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 $f_{sv} = fs = 555.55$

with $Es_v = Es = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.34843568$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.16544428$

$v = Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.30832797$

and confined core properties:

$b = 190.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 20.00$

$cc (5A.5, TBDY) = 0.002$

$c = \text{confinement factor} = 1.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.48456674$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.23008205$

$v = Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.42878928$

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 not satisfied

Case/Assumption Rejected.

New Case/Assumption: Unconfined full section - Spalling of concrete cover

' satisfies Eq. (4.4)

$v < s_{y1}$ - LHS eq.(4.7) is not satisfied

$v < v_{c,y1}$ - RHS eq.(4.6) is satisfied

$cu (4.10) = 0.35203969$

$M_{Rc} (4.17) = 6.2207E+008$

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- b , d , d' replaced by geometric parameters of the core: b_o , d_o , d'_o

- N , 1, 2, v normalised to $b_o \cdot d_o$, instead of $b \cdot d$

- parameters of confined concrete, f_{cc} , cc , used in lieu of f_c , ecu

Subcase: Rupture of tension steel

$v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

$v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

Subcase rejected

--->
New Subcase: Failure of compression zone

--->
 $v^* < v^*c,y2$ - LHS eq.(4.6) is not satisfied

--->
 $v^* < v^*c,y1$ - RHS eq.(4.6) is satisfied

--->
 $*cu$ (4.10) = 0.4588808
MRo (4.17) = 5.3907E+008

--->
 $u = cu$ (4.2) = 8.2702663E-006
Mu = MRo

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld \geq 1

Calculation of Mu1-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 6.8293729E-005$
Mu = 6.6013E+008

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00132912$
 $N = 8883.864$
 $fc = 20.00$
 co (5A.5, TBDY) = 0.002
Final value of cu : $cu^* = shear_factor * Max(cu, cc) = 0.0056977$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $cu = 0.0056977$

we (5.4c) = 0.00301868
 $ase = Max(((Aconf,max - AnoConf)/Aconf,max) * (Aconf,min/Aconf,max), 0) = 0.15755901$
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.
 $Aconf,min = 71100.00$ 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).
 $psh,min = Min(psh,x, psh,y) = 0.00229911$
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) = $Lstir * Astir / (Asec * s) = 0.00229911$
 $Lstir$ (Length of stirrups along Y) = 1460.00
 $Astir$ (stirrups area) = 78.53982
 $Asec$ (section area) = 237500.00

 psh,y ((5.4d), TBDY) = $Lstir * Astir / (Asec * s) = 0.00229911$
 $Lstir$ (Length of stirrups along X) = 1460.00
 $Astir$ (stirrups area) = 78.53982
 $Asec$ (section area) = 237500.00

 $s = 210.00$

fywe = 555.55

fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.06893512

2 = Asl,com/(b*d)*(fs2/fc) = 0.14518153

v = Asl,mid/(b*d)*(fsv/fc) = 0.12846999

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.0809548

2 = Asl,com/(b*d)*(fs2/fc) = 0.17049571

v = Asl,mid/(b*d)*(fsv/fc) = 0.1508703

Case/Assumption: Unconfinedsd 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) = 0.15877155

$M_u = M_{Rc}$ (4.15) = 6.6013E+008

$u = s_u$ (4.1) = 6.8293729E-005

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of M_{u2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 8.2702663E-006$

$M_u = 5.3907E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

ω (5A.5, TBDY) = 0.002

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0056977$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.0056977$

w_e (5.4c) = 0.00301868

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$

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.

$A_{conf,min} = 71100.00$ 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 210.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.002$

$c = \text{confinement factor} = 1.00$
 $y1 = 0.00231479$
 $sh1 = 0.008$
 $ft1 = 666.66$
 $fy1 = 555.55$
 $su1 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 1.00$
 $su1 = 0.4 * esu1_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu1_nominal = 0.08$,
 For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
 characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs1 = fs = 555.55$
 with $Es1 = Es = 200000.00$
 $y2 = 0.00231479$
 $sh2 = 0.008$
 $ft2 = 666.66$
 $fy2 = 555.55$
 $su2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/lb,min = 1.00$
 $su2 = 0.4 * esu2_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs2 = fs = 555.55$
 with $Es2 = Es = 200000.00$
 $yv = 0.00231479$
 $shv = 0.008$
 $ftv = 666.66$
 $fyv = 555.55$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 1.00$
 $suv = 0.4 * esuv_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 555.55$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.34843568$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.16544428$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.30832797$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, \text{TBDY}) = 20.00$
 $cc (5A.5, \text{TBDY}) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.48456674$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.23008205$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.42878928$
 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 not satisfied

Case/Assumption Rejected.

New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)

v < sy1 - LHS eq.(4.7) is not satisfied

v < vc,y1 - RHS eq.(4.6) is satisfied

cu (4.10) = 0.35203969

MRC (4.17) = 6.2207E+008

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu

Subcase: Rupture of tension steel

v* < v*s,y2 - LHS eq.(4.5) is not satisfied

v* < v*s,c - LHS eq.(4.5) is not satisfied

Subcase rejected

New Subcase: Failure of compression zone

v* < v*c,y2 - LHS eq.(4.6) is not satisfied

v* < v*c,y1 - RHS eq.(4.6) is satisfied

*cu (4.10) = 0.4588808

MRO (4.17) = 5.3907E+008

u = cu (4.2) = 8.2702663E-006

Mu = MRO

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 6.8293729E-005

Mu = 6.6013E+008

with full section properties:

b = 600.00

d = 557.00

d' = 43.00

v = 0.00132912

N = 8883.864

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.0056977

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.0056977

$$w_e (5.4c) = 0.00301868$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

$$L_{stir} (\text{Length of stirrups along X}) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

From ((5.A5), TBDY), TBDY: $c_c = 0.002$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs_1 = fs = 555.55$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$$

$$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs_2 = fs = 555.55$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

$f_{yv} = 555.55$
 $s_{uv} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$
 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 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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 555.55$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.06893512$
 $2 = A_{s1,com}/(b*d)*(f_{s2}/f_c) = 0.14518153$
 $v = A_{s1,mid}/(b*d)*(f_{sv}/f_c) = 0.12846999$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.0809548$
 $2 = A_{s1,com}/(b*d)*(f_{s2}/f_c) = 0.17049571$
 $v = A_{s1,mid}/(b*d)*(f_{sv}/f_c) = 0.1508703$
 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
 --->
 $s_u (4.8) = 0.15877155$
 $M_u = MR_c (4.15) = 6.6013E+008$
 $u = s_u (4.1) = 6.8293729E-005$

 Calculation of ratio l_b/l_d

 Adequate Lap Length: $l_b/l_d \geq 1$

 Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227298.208$

Calculation of Shear Strength at edge 1, $V_{r1} = 227298.208$
 $V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = k_{nl} * V_{Co10}$
 $V_{Co10} = 227298.208$
 $k_{nl} = 1$ (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)
 $f'_c = 20.00$, but $f_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 47.14131$
 $V_u = 0.00016213$
 $d = 0.8 * h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 159571.364$
 where:
 $V_{s1} = 159571.364$ is calculated for section web, with:

d = 480.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs1 is multiplied by Col1 = 1.00
s/d = 0.4375
Vs2 = 0.00 is calculated for section flange, with:
d = 200.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs2 is multiplied by Col2 = 0.00
s/d = 1.05
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 356502.845
bw = 250.00

Calculation of Shear Strength at edge 2, Vr2 = 227298.208
Vr2 = VCol ((10.3), ASCE 41-17) = knl*VCol0
VCol0 = 227298.208
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' = 20.00, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 47.14134
Vu = 0.00016213
d = 0.8*h = 480.00
Nu = 8883.864
Ag = 150000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 159571.364
where:
Vs1 = 159571.364 is calculated for section web, with:
d = 480.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs1 is multiplied by Col1 = 1.00
s/d = 0.4375
Vs2 = 0.00 is calculated for section flange, with:
d = 200.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs2 is multiplied by Col2 = 0.00
s/d = 1.05
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 356502.845
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: rdcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

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, $L = 3000.00$
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou, min} >= 1$)
No FRP Wrapping

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 0.00016213$
EDGE -B-
Shear Force, $V_b = -0.00016213$
BOTH EDGES
Axial Force, $F = -8883.864$
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, $V_e/V_r = 1.93617$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 440088.681$
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 6.6013E+008$
 $M_{u1+} = 5.3907E+008$, 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
 $M_{u1-} = 6.6013E+008$, 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
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 6.6013E+008$
 $M_{u2+} = 5.3907E+008$, 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
 $M_{u2-} = 6.6013E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 8.2702663E-006$$

$$\mu = 5.3907E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00318999$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0056977$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.0056977$$

$$\phi_{ue} (5.4c) = 0.00301868$$

$$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00229911$$

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)

$$\phi_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$\phi_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

$$L_{stir} (\text{Length of stirrups along X}) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{1,nominal} = 0.08,$$

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.

$$\text{with } fs_1 = fs = 555.55$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

```

ft2 = 666.66
fy2 = 555.55
su2 = 0.032
  using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
  and also multiplied by the shear_factor according to 15.7.1.4, with
  Shear_factor = 1.00
  lo/lou,min = lb/lb,min = 1.00
  su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
  From table 5A.1, TBDY: esu2_nominal = 0.08,
  For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
  characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
  y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.
  with fs2 = fs = 555.55
  with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
  using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
  and also multiplied by the shear_factor according to 15.7.1.4, with
  Shear_factor = 1.00
  lo/lou,min = lb/d = 1.00
  suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
  From table 5A.1, TBDY: esuv_nominal = 0.08,
  considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
  For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
  characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
  y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.
  with fsv = fs = 555.55
  with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.34843568
2 = Asl,com/(b*d)*(fs2/fc) = 0.16544428
v = Asl,mid/(b*d)*(fsv/fc) = 0.30832797
and confined core properties:
b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 20.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.48456674
2 = Asl,com/(b*d)*(fs2/fc) = 0.23008205
v = Asl,mid/(b*d)*(fsv/fc) = 0.42878928
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 not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.35203969
MRc (4.17) = 6.2207E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d

```

- - parameters of confined concrete, f_{cc} , cc , used in lieu of f_c , ecu

---->

Subcase: Rupture of tension steel

---->

$v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->

$v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

---->

Subcase rejected

---->

New Subcase: Failure of compression zone

---->

$v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

---->

$v^* < v^*_{c,y1}$ - RHS eq.(4.6) is satisfied

---->

$*cu$ (4.10) = 0.4588808

M_{Ro} (4.17) = 5.3907E+008

---->

$u = cu$ (4.2) = 8.2702663E-006

$\mu = M_{Ro}$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_{u1} -

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$u = 6.8293729E-005$

$\mu_u = 6.6013E+008$

with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00132912$

$N = 8883.864$

$f_c = 20.00$

ω (5A.5, TBDY) = 0.002

Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0056977$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.0056977$

w_e (5.4c) = 0.00301868

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$

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.

$A_{conf,min} = 71100.00$ 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

L_{stir} (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) = 0.00229911
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 210.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.002
c = confinement factor = 1.00

y1 = 0.00231479
sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.06893512

2 = Asl,com/(b*d)*(fs2/fc) = 0.14518153

v = Asl,mid/(b*d)*(fsv/fc) = 0.12846999

and confined core properties:

b = 540.00

$d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.0809548$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.17049571$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.1508703$
 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
 --->

$s_u (4.8) = 0.15877155$
 $M_u = MR_c (4.15) = 6.6013E+008$
 $u = s_u (4.1) = 6.8293729E-005$

 Calculation of ratio l_b/d

 Adequate Lap Length: $l_b/d \geq 1$

 Calculation of M_{u2+}

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 8.2702663E-006$
 $M_u = 5.3907E+008$

with full section properties:

$b = 250.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.0031899$
 $N = 8883.864$
 $f_c = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0056977$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.0056977$
 we (5.4c) = 0.00301868

$ase = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.15755901$
 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.
 $A_{conf,min} = 71100.00$ 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).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$
 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)

 $p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$
 L_{stir} (Length of stirrups along Y) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

$$\text{psh,y ((5.4d), TBDY)} = \text{Lstir} \cdot \text{Astir} / (\text{Asec} \cdot \text{s}) = 0.00229911$$

$$\text{Lstir (Length of stirrups along X)} = 1460.00$$

$$\text{Astir (stirrups area)} = 78.53982$$

$$\text{Asec (section area)} = 237500.00$$

$$\text{s} = 210.00$$

$$\text{fywe} = 555.55$$

$$\text{fce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: cc} = 0.002$$

$$\text{c} = \text{confinement factor} = 1.00$$

$$\text{y1} = 0.00231479$$

$$\text{sh1} = 0.008$$

$$\text{ft1} = 666.66$$

$$\text{fy1} = 555.55$$

$$\text{su1} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/ld} = 1.00$$

$$\text{su1} = 0.4 \cdot \text{esu1_nominal ((5.5), TBDY)} = 0.032$$

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 $\text{Min}(1, 1.25 \cdot (\text{lb/ld})^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with fs1} = \text{fs} = 555.55$$

$$\text{with Es1} = \text{Es} = 200000.00$$

$$\text{y2} = 0.00231479$$

$$\text{sh2} = 0.008$$

$$\text{ft2} = 666.66$$

$$\text{fy2} = 555.55$$

$$\text{su2} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/lb,min} = 1.00$$

$$\text{su2} = 0.4 \cdot \text{esu2_nominal ((5.5), TBDY)} = 0.032$$

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 $\text{Min}(1, 1.25 \cdot (\text{lb/ld})^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with fs2} = \text{fs} = 555.55$$

$$\text{with Es2} = \text{Es} = 200000.00$$

$$\text{yv} = 0.00231479$$

$$\text{shv} = 0.008$$

$$\text{ftv} = 666.66$$

$$\text{fyv} = 555.55$$

$$\text{su} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/ld} = 1.00$$

$$\text{su} = 0.4 \cdot \text{esuv_nominal ((5.5), TBDY)} = 0.032$$

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 $\text{Min}(1, 1.25 \cdot (\text{lb/ld})^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with fsv} = \text{fs} = 555.55$$

$$\text{with Esv} = \text{Es} = 200000.00$$

$$1 = \text{Asl,ten} / (\text{b} \cdot \text{d}) \cdot (\text{fs1} / \text{fc}) = 0.34843568$$

$$2 = \text{Asl,com} / (\text{b} \cdot \text{d}) \cdot (\text{fs2} / \text{fc}) = 0.16544428$$

$$\text{v} = \text{Asl,mid} / (\text{b} \cdot \text{d}) \cdot (\text{fsv} / \text{fc}) = 0.30832797$$

and confined core properties:

$$\text{b} = 190.00$$

$$\text{d} = 527.00$$

$$\text{d}' = 13.00$$

$$\text{fcc (5A.2, TBDY)} = 20.00$$

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.48456674

2 = Asl,com/(b*d)*(fs2/fc) = 0.23008205

v = Asl,mid/(b*d)*(fsv/fc) = 0.42878928

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 not satisfied

---->
Case/Assumption Rejected.

---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)

---->
v < s,y1 - LHS eq.(4.7) is not satisfied

---->
v < vc,y1 - RHS eq.(4.6) is satisfied

---->
cu (4.10) = 0.35203969
MRc (4.17) = 6.2207E+008

---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu

---->
Subcase: Rupture of tension steel

---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied

---->
v* < v*s,c - LHS eq.(4.5) is not satisfied

---->
Subcase rejected

---->
New Subcase: Failure of compression zone

---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied

---->
v* < v*c,y1 - RHS eq.(4.6) is satisfied

---->
*cu (4.10) = 0.4588808
MRo (4.17) = 5.3907E+008

---->
u = cu (4.2) = 8.2702663E-006
Mu = MRo

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 6.8293729E-005
Mu = 6.6013E+008

with full section properties:
b = 600.00

d = 557.00

d' = 43.00

v = 0.00132912

N = 8883.864

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0056977$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.0056977$

we (5.4c) = 0.00301868

ase = $\text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.15755901$

The definitions of A_{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.

$A_{\text{conf,min}}$ = 71100.00 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_{noConf} = 105733.333 is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

psh,min = $\text{Min}(psh,x, psh,y) = 0.00229911$

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) = $L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00229911$

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = $L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00229911$

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 210.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: $cc = 0.002$

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

su1 = $0.4 * esu1_{\text{nominal}} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu1_{\text{nominal}} = 0.08$,

For calculation of $esu1_{\text{nominal}}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 555.55$

with $Es1 = Es = 200000.00$

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = $0.4 * esu2_{\text{nominal}} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $es_{u2_nominal} = 0.08$,

For calculation of $es_{u2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fs_{y2} = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$lo/lo_{u,min} = lb/d = 1.00$

$suv = 0.4 \cdot es_{u2_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,

considering characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY

For calculation of $es_{uv_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_v = fs = 555.55$

with $Es_v = Es = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.06893512$

2 = $As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.14518153$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.12846999$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 20.00$

$cc (5A.5, TBDY) = 0.002$

$c = \text{confinement factor} = 1.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.0809548$

2 = $As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.17049571$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.1508703$

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

--->

$su (4.8) = 0.15877155$

$Mu = MRc (4.15) = 6.6013E+008$

$u = su (4.1) = 6.8293729E-005$

Calculation of ratio lb/d

Adequate Lap Length: $lb/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227298.208$

Calculation of Shear Strength at edge 1, $V_{r1} = 227298.208$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{Col0}$

$V_{Col0} = 227298.208$

$knl = 1$ (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)

$f_c' = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$
 $\mu_u = 47.13723$
 $V_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 159571.364$
 where:
 $V_{s1} = 0.00$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 210.00$
 V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 1.05$
 $V_{s2} = 159571.364$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 210.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.4375$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 227298.208$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{Col0}$
 $V_{Col0} = 227298.208$
 $knl = 1$ (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)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 47.13721$
 $V_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 159571.364$
 where:
 $V_{s1} = 0.00$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 210.00$
 V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 1.05$
 $V_{s2} = 159571.364$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 210.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.4375$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

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: 2

Integration Section: (b)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/l_d > 1$)

No FRP Wrapping

Stepwise Properties

Bending Moment, $M = -120136.814$

Shear Force, $V_2 = 4235.571$

Shear Force, $V_3 = -145.8655$

Axial Force, $F = -9654.265$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl} = 0.00$

-Compression: $A_{sc} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1746.726$

-Compression: $A_{sl,com} = 829.3805$

-Middle: $A_{sl,mid} = 1545.664$

Mean Diameter of Tension Reinforcement, $Db_L = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \gamma \cdot u = 0.03163777$

$u = \gamma \cdot u_{,R} = 0.03163777$

- Calculation of γ -

$\gamma = (M \cdot L_s / 3) / E_{eff} = 0.0030655$ ((4.29), Biskinis Phd))

$M \cdot L_s = 4.6810E+008$

$L_s = M / V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 823.6137

From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 4.1921E+013$

factor = 0.30

$A_g = 237500.00$

$f_c' = 20.00$

$N = 9654.265$

$E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 6.47111079\text{E-}006$
with $f_y = 444.44$
 $d = 557.00$
 $y = 0.38347696$
 $A = 0.02975578$
 $B = 0.01913802$
with $p_t = 0.01254381$
 $p_c = 0.00595605$
 $p_v = 0.01109992$
 $N = 9654.265$
 $b = 250.00$
 $\rho = 0.07719928$
 $y_{\text{comp}} = 8.02411107\text{E-}006$
with $f_c = 20.00$
 $E_c = 21019.039$
 $y = 0.38321062$
 $A = 0.02939738$
 $B = 0.01898202$
with $E_s = 200000.00$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

- Calculation of ρ -

From table 10-8: $\rho = 0.02857227$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/d < 1$

shear control ratio $V_y E / V_{CoI} E = 1.93617$

$d = 557.00$

$s = 0.00$

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$, 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.

$N_{UD} = 9654.265$

$A_g = 237500.00$

$f_{cE} = 20.00$

$f_{yE} = f_{yI} E = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_{cE} = 20.00$

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

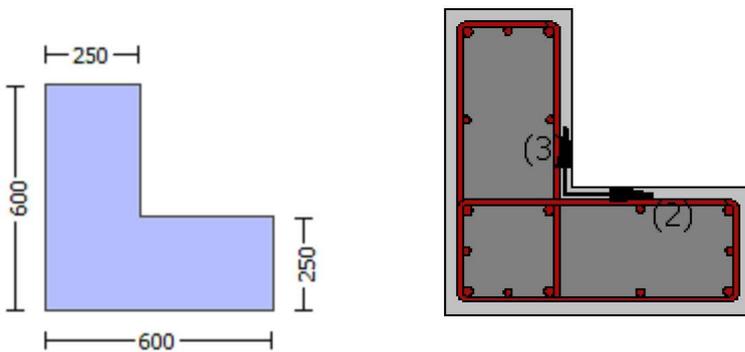
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

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, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{o,u,min} = l_b/l_d \geq 1$)
No FRP Wrapping

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -315855.763$
Shear Force, $V_a = 145.8655$
EDGE -B-
Bending Moment, $M_b = -120136.814$
Shear Force, $V_b = -145.8655$
BOTH EDGES
Axial Force, $F = -9654.265$
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, $D_{bL,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = *V_n = 265105.864$
 V_n ((10.3), ASCE 41-17) = $k_n l * V_{CoI0} = 265105.864$
 $V_{CoI} = 265105.864$
 $k_n l = 1.00$
 $displacement_ductility_demand = 7.6185954E-006$

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)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 120136.814$
 $V_u = 145.8655$
 $d = 0.8 * h = 480.00$
 $N_u = 9654.265$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 143615.664$
where:
 $V_{s1} = 143615.664$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 210.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.4375$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 210.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.05$
 V_f ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: $V_s + V_f \leq 318865.838$
 $bw = 250.00$

 $displacement_ductility_demand$ is calculated as / y

- Calculation of ϕ_y for END B -
for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 2.3354821E-008$
 $y = (M_y * L_s / 3) / E_{eff} = 0.0030655$ ((4.29), Biskinis Phd))
 $M_y = 4.6810E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 823.6137
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1921E+013$
factor = 0.30
Ag = 237500.00
fc' = 20.00
N = 9654.265
 $E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of ϕ_y and M_y according to Annex 7 -

 $y = \text{Min}(\phi_{y_ten}, \phi_{y_com})$
 $\phi_{y_ten} = 6.4711079E-006$
with $f_y = 444.44$
d = 557.00
 $y = 0.38347696$
A = 0.02975578
B = 0.01913802
with pt = 0.01254381
pc = 0.00595605
pv = 0.01109992
N = 9654.265
b = 250.00
" = 0.07719928
 $\phi_{y_comp} = 8.0241107E-006$
with fc = 20.00
Ec = 21019.039
 $y = 0.38321062$
A = 0.02939738
B = 0.01898202
with Es = 200000.00

Calculation of ratio I_b/I_d

Adequate Lap Length: $I_b/I_d \geq 1$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1
At local axis: 3
Integration Section: (b)

Calculation No. 16

column C1, Floor 1

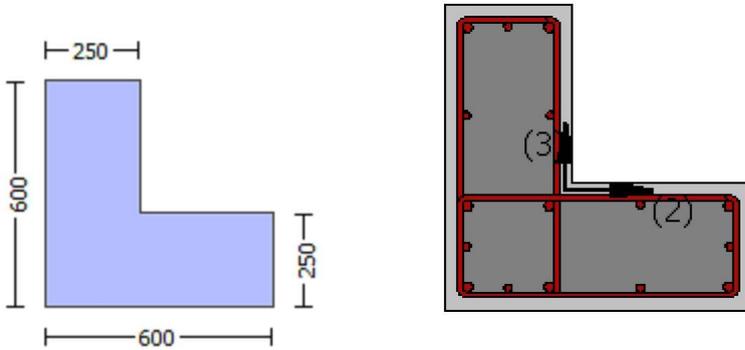
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_r)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou,min} \geq 1$)

No FRP Wrapping

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 0.00016213$
EDGE -B-
Shear Force, $V_b = -0.00016213$
BOTH EDGES
Axial Force, $F = -8883.864$
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, $V_e/V_r = 1.93617$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 440088.681$

with
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 6.6013E+008$
 $Mu_{1+} = 5.3907E+008$, 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
 $Mu_{1-} = 6.6013E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 6.6013E+008$
 $Mu_{2+} = 5.3907E+008$, 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
 $Mu_{2-} = 6.6013E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 8.2702663E-006$
 $M_u = 5.3907E+008$

with full section properties:

$b = 250.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.0031899$
 $N = 8883.864$
 $f_c = 20.00$
 α_1 (5A.5, TBDY) = 0.002
Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0056977$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_u = 0.0056977$
 ω_e (5.4c) = 0.00301868
 $\alpha_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.15755901$
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.
 $A_{conf,min} = 71100.00$ 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).
 $\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00229911$
Expression ((5.4d), TBDY) for $\phi_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 210.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = $0.4 * esu1_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = $0.4 * esu2_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

suv = $0.4 * esuv_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = $Asl,ten / (b * d) * (fs1 / fc) = 0.34843568$

2 = $Asl,com / (b * d) * (fs2 / fc) = 0.16544428$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.30832797$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 20.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.48456674$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.23008205$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.42878928$$

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 not satisfied

Case/Assumption Rejected.

New Case/Assumption: Unconfined full section - Spalling of concrete cover

' satisfies Eq. (4.4)

$v < s_{y1}$ - LHS eq.(4.7) is not satisfied

$v < v_{c,y1}$ - RHS eq.(4.6) is satisfied

$$c_u (4.10) = 0.35203969$$

$$MR_c (4.17) = 6.2207E+008$$

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o
- $N, 1, 2, v$ normalised to b_o*d_o , instead of $b*d$
- - parameters of confined concrete, f_{cc}, c_c , used in lieu of f_c, c_u

Subcase: Rupture of tension steel

$v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

$v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

Subcase rejected

New Subcase: Failure of compression zone

$v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

$v^* < v^*_{c,y1}$ - RHS eq.(4.6) is satisfied

$$*c_u (4.10) = 0.4588808$$

$$MR_o (4.17) = 5.3907E+008$$

$$u = c_u (4.2) = 8.2702663E-006$$

$$\mu_u = MR_o$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of μ_{u1} -

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 6.8293729E-005$$

$$\mu = 6.6013E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0056977$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.0056977$$

$$\phi_{ue} \text{ (5.4c)} = 0.00301868$$

$$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00229911$$

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)

$$\phi_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$\phi_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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 $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/lb_{u,min} = 1.00$$

$$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_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.

$$\text{with } fs_2 = fs = 555.55$$

$$\text{with } Es_2 = Es = 200000.00$$

$$yv = 0.00231479$$

$$shv = 0.008$$

$$ftv = 666.66$$

$$fyv = 555.55$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/ld = 1.00$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_{nominal}$ and yv, shv, ftv, fyv , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

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.

$$\text{with } fsv = fs = 555.55$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.06893512$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.14518153$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.12846999$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 20.00$$

$$cc (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.0809548$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.17049571$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.1508703$$

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

---->

$$su (4.8) = 0.15877155$$

$$Mu = MRc (4.15) = 6.6013E+008$$

$$u = su (4.1) = 6.8293729E-005$$

Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of Mu_{2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 8.2702663E-006$$

$$Mu = 5.3907E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0056977$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0056977$$

$$w_e \text{ (5.4c)} = 0.00301868$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{1,nominal} = 0.08,$$

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.

$$\text{with } fs_1 = fs = 555.55$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00
 lo/lou,min = lb/lb,min = 1.00
 su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
 From table 5A.1, TBDY: esu2_nominal = 0.08,
 For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
 characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
 y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE41-17.
 with fs2 = fs = 555.55
 with Es2 = Es = 200000.00
 yv = 0.00231479
 shv = 0.008
 ftv = 666.66
 fyv = 555.55
 suv = 0.032
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 lo/lou,min = lb/lb = 1.00
 suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
 From table 5A.1, TBDY: esuv_nominal = 0.08,
 considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
 For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
 characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
 y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE41-17.
 with fsv = fs = 555.55
 with Esv = Es = 200000.00
 1 = Asl,ten/(b*d)*(fs1/fc) = 0.34843568
 2 = Asl,com/(b*d)*(fs2/fc) = 0.16544428
 v = Asl,mid/(b*d)*(fsv/fc) = 0.30832797
 and confined core properties:
 b = 190.00
 d = 527.00
 d' = 13.00
 fcc (5A.2, TBDY) = 20.00
 cc (5A.5, TBDY) = 0.002
 c = confinement factor = 1.00
 1 = Asl,ten/(b*d)*(fs1/fc) = 0.48456674
 2 = Asl,com/(b*d)*(fs2/fc) = 0.23008205
 v = Asl,mid/(b*d)*(fsv/fc) = 0.42878928
 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 not satisfied
 --->
 Case/Assumption Rejected.
 --->
 New Case/Assumption: Unconfined full section - Spalling of concrete cover
 ' satisfies Eq. (4.4)
 --->
 v < s,y1 - LHS eq.(4.7) is not satisfied
 --->
 v < vc,y1 - RHS eq.(4.6) is satisfied
 --->
 cu (4.10) = 0.35203969
 MRc (4.17) = 6.2207E+008
 --->
 New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
 In expressions below, the following modifications have been made
 - b, d, d' replaced by geometric parameters of the core: bo, do, d'o
 - N, 1, 2, v normalised to bo*do, instead of b*d
 - - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
 --->
 Subcase: Rupture of tension steel
 --->
 v* < v*s,y2 - LHS eq.(4.5) is not satisfied

--->
v* < v*s,c - LHS eq.(4.5) is not satisfied

--->
Subcase rejected

--->
New Subcase: Failure of compression zone

--->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied

--->
v* < v*c,y1 - RHS eq.(4.6) is satisfied

--->
*cu (4.10) = 0.4588808

MRO (4.17) = 5.3907E+008

--->
u = cu (4.2) = 8.2702663E-006
Mu = MRO

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 6.8293729E-005

Mu = 6.6013E+008

with full section properties:

b = 600.00

d = 557.00

d' = 43.00

v = 0.00132912

N = 8883.864

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.0056977

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.0056977

we (5.4c) = 0.00301868

ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.15755901

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 = 71100.00 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) = 0.00229911

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) = 0.00229911

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) = 0.00229911

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 210.00

fywe = 555.55

fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.06893512

2 = Asl,com/(b*d)*(fs2/fc) = 0.14518153

v = Asl,mid/(b*d)*(fsv/fc) = 0.12846999

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.0809548$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.17049571$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.1508703$$

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) = 0.15877155
 μ_u = M/R_c (4.15) = 6.6013E+008
 u = s_u (4.1) = 6.8293729E-005

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227298.208$

Calculation of Shear Strength at edge 1, $V_{r1} = 227298.208$

$V_{r1} = V_{Co1}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Co10}$

$$V_{Co10} = 227298.208$$

$k_{nl} = 1$ (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)

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$$\mu_u = 47.14131$$

$$v_u = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 159571.364$$

where:

$V_{s1} = 159571.364$ is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 210.00$$

V_{s1} is multiplied by $Col1 = 1.00$

$$s/d = 0.4375$$

$V_{s2} = 0.00$ is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 210.00$$

V_{s2} is multiplied by $Col2 = 0.00$

$$s/d = 1.05$$

V_f ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$

$$b_w = 250.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 227298.208$

$V_{r2} = V_{Co2}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Co10}$

$$V_{Co10} = 227298.208$$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'

where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$M_u = 47.14134$

$V_u = 0.00016213$

$d = 0.8 \cdot h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 159571.364$

where:

$V_{s1} = 159571.364$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.4375$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 210.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.05$

V_f ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$

$b_w = 250.00$

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, = 1.00

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

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, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou,min} > 1$)
No FRP Wrapping

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 0.00016213$
EDGE -B-
Shear Force, $V_b = -0.00016213$
BOTH EDGES
Axial Force, $F = -8883.864$
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: $As_{c,mid} = 1545.664$

Calculation of Shear Capacity ratio , $V_e/V_r = 1.93617$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 440088.681$
with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 6.6013E+008$
 $\mu_{u1+} = 5.3907E+008$, 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
 $\mu_{u1-} = 6.6013E+008$, 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
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 6.6013E+008$
 $\mu_{u2+} = 5.3907E+008$, 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
 $\mu_{u2-} = 6.6013E+008$, 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 μ_{u1+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:
 $\mu_u = 8.2702663E-006$
 $\mu_u = 5.3907E+008$

with full section properties:

$b = 250.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00318999$
 $N = 8883.864$
 $f_c = 20.00$
 $co (5A.5, TBDY) = 0.002$
Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.0056977$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\mu_u = 0.0056977$
 $\mu_u (5.4c) = 0.00301868$
 $\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.15755901$
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.

$A_{conf,min} = 71100.00$ 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 210.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.002$

$c = \text{confinement factor} = 1.00$

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$su_1 = 0.4 * esu_{1,nominal}$ ((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 $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 * esu_{2,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$su_v = 0.4 * esu_{v,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv,ftv,fyv , it is considered
 characteristic value $fsv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1,ft1,fy1$, are also multiplied by $Min(1,1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 555.55$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.34843568$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.16544428$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.30832797$

and confined core properties:

$b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 fcc (5A.2, TBDY) = 20.00
 cc (5A.5, TBDY) = 0.002
 $c =$ confinement factor = 1.00
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.48456674$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.23008205$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.42878928$

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 not satisfied

---->
 Case/Assumption Rejected.

---->
 New Case/Assumption: Unconfined full section - Spalling of concrete cover
 ' satisfies Eq. (4.4)

---->
 $v < s,y1$ - LHS eq.(4.7) is not satisfied

---->
 $v < vc,y1$ - RHS eq.(4.6) is satisfied

---->
 cu (4.10) = 0.35203969
 MRC (4.17) = 6.2207E+008

---->
 New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
 In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: $bo, do, d'o$
- $N, 1, 2, v$ normalised to $bo*do$, instead of $b*d$
- parameters of confined concrete, fcc, cc , used in lieu of fc, ecu

---->
 Subcase: Rupture of tension steel

---->
 $v^* < v^*,y2$ - LHS eq.(4.5) is not satisfied

---->
 $v^* < v^*,c$ - LHS eq.(4.5) is not satisfied

---->
 Subcase rejected

---->
 New Subcase: Failure of compression zone

---->
 $v^* < v^*,y2$ - LHS eq.(4.6) is not satisfied

---->
 $v^* < v^*,y1$ - RHS eq.(4.6) is satisfied

---->
 $*cu$ (4.10) = 0.4588808
 MRO (4.17) = 5.3907E+008

---->
 $u = cu$ (4.2) = 8.2702663E-006
 $Mu = MRO$

 Calculation of ratio lb/ld

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_1 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 6.8293729E-005$$

$$\mu = 6.6013E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0056977$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0056977$$

$$w_e \text{ (5.4c)} = 0.00301868$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00229911$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 555.55$

with $Es1 = Es = 200000.00$

$y2 = 0.00231479$

$sh2 = 0.008$

$ft2 = 666.66$

$fy2 = 555.55$

$su2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lou, min = lb/lb, min = 1.00$

$su2 = 0.4 \cdot esu2_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 555.55$

with $Es2 = Es = 200000.00$

$yv = 0.00231479$

$shv = 0.008$

$ftv = 666.66$

$fyv = 555.55$

$suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lou, min = lb/ld = 1.00$

$suv = 0.4 \cdot esuv_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fsv = fs = 555.55$

with $Esv = Es = 200000.00$

$1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.06893512$

$2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.14518153$

$v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.12846999$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 20.00$

$cc (5A.5, TBDY) = 0.002$

$c = \text{confinement factor} = 1.00$

$1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.0809548$

$2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.17049571$

$v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.1508703$

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

$su (4.8) = 0.15877155$

$Mu = MRc (4.15) = 6.6013E+008$

$u = su (4.1) = 6.8293729E-005$

Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of Mu2+

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 8.2702663E-006$$

$$Mu = 5.3907E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$cc \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0056977$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.0056977$$

$$we \text{ (5.4c)} = 0.00301868$$

$$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.15755901$$

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.

$A_{conf,min} = 71100.00$ 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).

$$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00229911$$

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)

$$psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00229911$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou_{min} = lb/d = 1.00$$

$$su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

```

with fs1 = fs = 555.55
with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE41-17.
with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.34843568
2 = Asl,com/(b*d)*(fs2/fc) = 0.16544428
v = Asl,mid/(b*d)*(fsv/fc) = 0.30832797
and confined core properties:
b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 20.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.48456674
2 = Asl,com/(b*d)*(fs2/fc) = 0.23008205
v = Asl,mid/(b*d)*(fsv/fc) = 0.42878928
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 not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
'satisfies Eq. (4.4)
---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.35203969
MRc (4.17) = 6.2207E+008
---->

```

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ec

--->

Subcase: Rupture of tension steel

--->

$v^* < v^*s,y2$ - LHS eq.(4.5) is not satisfied

--->

$v^* < v^*s,c$ - LHS eq.(4.5) is not satisfied

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

$v^* < v^*c,y2$ - LHS eq.(4.6) is not satisfied

--->

$v^* < v^*c,y1$ - RHS eq.(4.6) is satisfied

--->

*cu (4.10) = 0.4588808

MRo (4.17) = 5.3907E+008

--->

u = cu (4.2) = 8.2702663E-006

Mu = MRo

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 6.8293729E-005

Mu = 6.6013E+008

with full section properties:

b = 600.00

d = 557.00

d' = 43.00

v = 0.00132912

N = 8883.864

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.0056977

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.0056977

we (5.4c) = 0.00301868

ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.15755901

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 = 71100.00 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) = 0.00229911

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)

$$\text{psh},x \text{ ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00229911$$

$$\text{Lstir (Length of stirrups along Y)} = 1460.00$$

$$\text{Astir (stirrups area)} = 78.53982$$

$$\text{Asec (section area)} = 237500.00$$

$$\text{psh},y \text{ ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00229911$$

$$\text{Lstir (Length of stirrups along X)} = 1460.00$$

$$\text{Astir (stirrups area)} = 78.53982$$

$$\text{Asec (section area)} = 237500.00$$

$$s = 210.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

$$su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 555.55$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00231479$$

$$sh2 = 0.008$$

$$ft2 = 666.66$$

$$fy2 = 555.55$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$$

$$su2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and $y2, sh2, ft2, fy2$, it is considered
characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 555.55$$

$$\text{with } Es2 = Es = 200000.00$$

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

$$fy_v = 555.55$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

$$suv = 0.4 * esuv_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, 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.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 555.55$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = A_{sl,ten} / (b * d) * (fs1 / fc) = 0.06893512$$

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.14518153$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.12846999$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 20.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.0809548$$

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.17049571$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.1508703$$

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

--->

$$s_u (4.8) = 0.15877155$$

$$M_u = M_{Rc} (4.15) = 6.6013E+008$$

$$u = s_u (4.1) = 6.8293729E-005$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227298.208$

Calculation of Shear Strength at edge 1, $V_{r1} = 227298.208$

$$V_{r1} = V_{CoI} ((10.3), ASCE 41-17) = k_{nl} * V_{CoI0}$$

$$V_{CoI0} = 227298.208$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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)

$$f_c' = 20.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$M_u = 47.13723$$

$$V_u = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 159571.364$$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 210.00$$

V_{s1} is multiplied by $Col1 = 0.00$

$$s/d = 1.05$$

$V_{s2} = 159571.364$ is calculated for section flange, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 210.00$$

V_{s2} is multiplied by $Col2 = 1.00$

$$s/d = 0.4375$$

$$V_f ((11-3)-(11.4), ACI 440) = 0.00$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 356502.845$$

bw = 250.00

Calculation of Shear Strength at edge 2, Vr2 = 227298.208
Vr2 = VCol ((10.3), ASCE 41-17) = knl*VCol0
VCol0 = 227298.208
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' = 20.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 47.13721
Vu = 0.00016213
d = 0.8*h = 480.00
Nu = 8883.864
Ag = 150000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 159571.364
where:
Vs1 = 0.00 is calculated for section web, with:
d = 200.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs1 is multiplied by Col1 = 0.00
s/d = 1.05
Vs2 = 159571.364 is calculated for section flange, with:
d = 480.00
Av = 157079.633
fy = 444.44
s = 210.00
Vs2 is multiplied by Col2 = 1.00
s/d = 0.4375
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 356502.845
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: (b)
Section Type: rclcs

Constant Properties

Knowledge Factor, = 1.00
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00
Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44
Concrete Elasticity, Ec = 21019.039
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

Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_b/l_d > 1$)
No FRP Wrapping

Stepwise Properties

Bending Moment, $M = 163326.055$
Shear Force, $V_2 = 4235.571$
Shear Force, $V_3 = -145.8655$
Axial Force, $F = -9654.265$
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, $DbL = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.02968887$
 $u = y + p = 0.02968887$

- Calculation of y -

$y = (My * L_s / 3) / E_{eff} = 0.0011166$ ((4.29), Biskinis Phd))
 $My = 4.6810E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1921E+013$
factor = 0.30
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9654.265$
 $E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 6.4711079E-006$
with $f_y = 444.44$
 $d = 557.00$
 $y = 0.38347696$
 $A = 0.02975578$
 $B = 0.01913802$
with $pt = 0.01254381$
 $pc = 0.00595605$
 $p_v = 0.01109992$
 $N = 9654.265$
 $b = 250.00$
 $" = 0.07719928$
 $y_{comp} = 8.0241107E-006$
with $f_c = 20.00$
 $E_c = 21019.039$
 $y = 0.38321062$
 $A = 0.02939738$

B = 0.01898202
with Es = 200000.00

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

- Calculation of p -

From table 10-8: p = 0.02857227

with:

- Columns controlled by inadequate development or splicing along the clear height because lb/d < 1
shear control ratio $V_y E / V_{Co} I_{OE} = 1.93617$

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.

$N_{UD} = 9654.265$

$A_g = 237500.00$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 0.00$

$p_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.02959978$

b = 250.00

d = 557.00

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)