

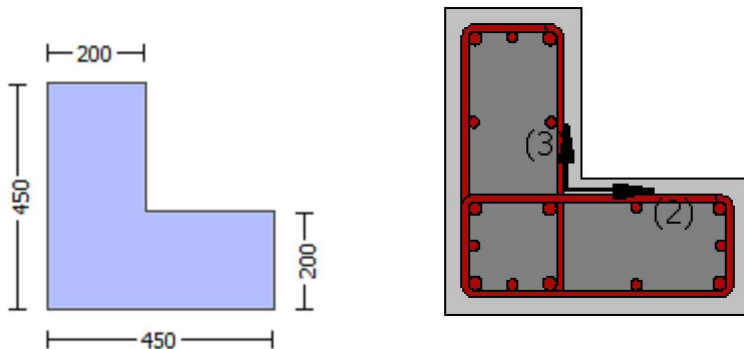
Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

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



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

Constant Properties

Knowledge Factor, $\gamma = 1.00$
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 10.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
Concrete Elasticity, $E_c = 18203.022$

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

Existing material: Concrete Strength, $f_c = f_{cm} = 15.00$

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

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Max Height, $H_{max} = 450.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 450.00$

Min Width, $W_{min} = 200.00$

Cover Thickness, $c = 25.00$

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, $M_a = -7.6058E+007$

Shear Force, $V_a = 114740.397$

EDGE -B-

Bending Moment, $M_b = 1.4356E+008$

Shear Force, $V_b = -114740.397$

BOTH EDGES

Axial Force, $F = -1.5617E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 1545.664$

-Compression: $A_{sc} = 2576.106$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

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

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = V_n = 172801.793$

$V_n ((10.3), ASCE 41-17) = k_n l V_{CoI0} = 172801.793$

$V_{CoI} = 246859.704$

$k_n l = 0.70$

displacement_ductility_demand = 50.54489

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)

$f'_c = 10.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 7.6058E+007$

$V_u = 114740.397$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.5617E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 50265.482$

where:

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

$d = 160.00$

$A_v = 157079.633$

$f_y = 400.00$
 $s = 300.00$
 V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 1.875$
 $V_{s2} = 50265.482$ is calculated for section flange, with:
 $d = 360.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 300.00$
 V_{s2} is multiplied by $Col2 = 0.66666667$
 $s/d = 0.83333333$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
 From $(11-11)$, ACI 440: $V_s + V_f \leq 151251.347$
 $b_w = 200.00$

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 $\theta = 0.05912288$
 $y = (M_y * L_s / 3) / E I_{eff} = 0.00116971 ((4.29), Biskinis Phd)$
 $M_y = 1.4757E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 662.8737
 From table 10.5, ASCE 41_17: $E I_{eff} = factor * E_c * I_g = 2.7875E+013$
 $factor = 0.70$
 $A_g = 140000.00$
 $f_c' = 15.00$
 $N = 1.5617E+006$
 $E_c * I_g = 3.9822E+013$

Calculation of Yielding Moment M_y

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

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 1.4507672E-005$
 with $f_y = 444.44$
 $d = 407.00$
 $y = 0.62365079$
 $A = 0.09380482$
 $B = 0.07620117$
 with $p_t = 0.02145854$
 $p_c = 0.01018895$
 $p_v = 0.0189885$
 $N = 1.5617E+006$
 $b = 200.00$
 $\rho = 0.10565111$
 $y_{comp} = 3.5726923E-006$
 with $f_c = 15.00$
 $E_c = 18203.022$
 $y = 1.02007$
 $A = -0.01403851$
 $B = 0.03303234$
 with $E_s = 200000.00$

Calculation of ratio I_b / I_d

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

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

Calculation No. 2

column C1, Floor 1

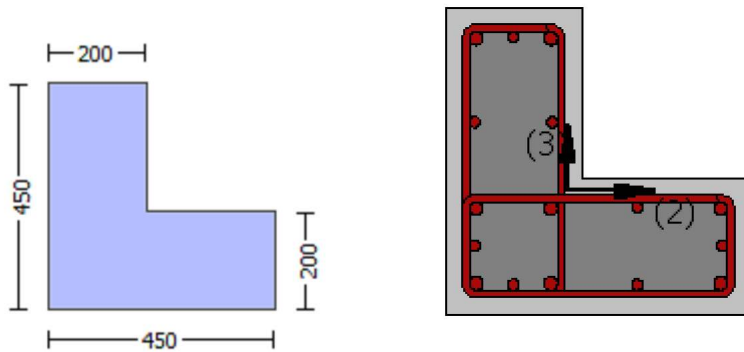
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ)

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, $f_c = f_{cm} = 15.00$

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

Concrete Elasticity, $E_c = 18203.022$

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, $H_{max} = 450.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 450.00$

Min Width, $W_{min} = 200.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length, $L = 3000.00$

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

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = 2.2161626E-006$
EDGE -B-
Shear Force, $V_b = -2.2161626E-006$
BOTH EDGES
Axial Force, $F = -1.5610E+006$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 716.2831$
-Compression: $As_c = 3091.327$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 829.3805$
-Compression: $As_{c,com} = 1746.726$
-Middle: $As_{c,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.8353$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 303967.895$
with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 4.5595E+008$
 $\mu_{u1+} = 4.5595E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u1-} = 2.0582E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 4.5595E+008$
 $\mu_{u2+} = 4.5595E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u2-} = 2.0582E+008$, 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_{u1+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:
 $\mu_u = 1.6866617E-005$
 $\mu_u = 4.5595E+008$

with full section properties:

$b = 450.00$
 $d = 407.00$
 $d' = 43.00$
 $v = 0.5682084$
 $N = 1.5610E+006$
 $f_c = 15.00$
 ϕ_o (5A.5, TBDY) = 0.002
Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \max(\phi_u, \phi_o) = 0.0035$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_u = 0.0035$
 ϕ_{ue} (5.4c) = 0.00
 $\phi_{ase} = \max(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.00$
The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

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

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.0019822$

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)

 $p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

 $p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

 $s = 300.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

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

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

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

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

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

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

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

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

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

with $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

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

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

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

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

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

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

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$su_v = 0.032$

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

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and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lo,min = lb/ld = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16771765
2 = Asl,com/(b*d)*(fs2/fc) = 0.35322354
v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.5098538
MRc (4.17) = 4.5595E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.56860508
MRo (4.18) = 3.5813E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 1.6866617E-005
Mu = MRc

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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:

$$\mu_u = 9.8367160E-006$$

$$\mu_{u1} = 2.0582E+008$$

with full section properties:

$$b = 200.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$\nu = 1.27847$$

$$N = 1.5610E+006$$

$$f_c = 15.00$$

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

$$\text{Final value of } \mu_{cu} = \text{shear_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.0035$$

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

$$\text{From (5.4b), TB DY: } \mu_{cu} = 0.0035$$

$$\text{we (5.4c) } = 0.00$$

$$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

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

$$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.0019822$$

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

$$\mu_{psh,x} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

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

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

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

$$\mu_{psh,y} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

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

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

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

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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


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lo/lou,min = lb/d = 1.00
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.
with fs1 = fs = 555.55
with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/d = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.79475296
2 = Asl,com/(b*d)*(fs2/fc) = 0.37736471
v = Asl,mid/(b*d)*(fsv/fc) = 0.7032706
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is not satisfied

```

```

---->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 9.8367160E-006
Mu = MRc
-----

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

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

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.6866617E-005
Mu = 4.5595E+008
-----

with full section properties:
b = 450.00
d = 407.00
d' = 43.00
v = 0.5682084
N = 1.5610E+006
fc = 15.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.0035
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.0035
we (5.4c) = 0.00
ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.00
The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization
of the rectangular sections confinement, which is expressed by (5.4d).
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)
"Theoretical Stress-Strain Model for Confined Concrete."
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
Aconf,max = 89600.00 is the confined core area at levels of member with hoops and
is calculated as the area of core enclosed by the center lines of the perimeter hoops.
Aconf,min = 0.00 is the confined core area at midway between the levels of hoops and

```

is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

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

psh,min = Min(psh,x , psh,y) = 0.0019822

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) = 0.0019822

Lstir (Length of stirrups along Y) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.0019822

Lstir (Length of stirrups along X) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

s = 300.00

fywe = 555.55

fce = 15.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

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

lo/lou,min = lb/lb = 1.00

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

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

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

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

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

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

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

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

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

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

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

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

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

lo/lou,min = lb/lb = 1.00

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

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

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

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

```

characteristic value  $f_{sv} = f_{sv}/1.2$ , 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, ASCE 41-17.
with  $f_{sv} = f_s = 555.55$ 
with  $E_{sv} = E_s = 200000.00$ 
1 =  $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.16771765$ 
2 =  $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.35322354$ 
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.31256471$ 
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 =  $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.20891986$ 
2 =  $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.4399979$ 
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.38935066$ 
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
 $v < v_{s,c}$  - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
 $v < s_{y1}$  - LHS eq.(4.7) is not satisfied
--->
 $v < v_{c,y1}$  - RHS eq.(4.6) is satisfied
--->
 $\epsilon_{cu}$  (4.10) = 0.5098538
 $M_{Rc}$  (4.17) = 4.5595E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core:  $b_o, d_o, d'_o$ 
-  $N_1, N_2, v$  normalised to  $b_o \cdot d_o$ , instead of  $b \cdot d$ 
- parameters of confined concrete, fcc, cc, used in lieu of  $f_c, \epsilon_{cu}$ 
--->
Subcase: Rupture of tension steel
--->
 $v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied
--->
 $v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
 $v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied
--->
 $v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied
--->
 $\epsilon^*_{cu}$  (4.11) = 0.56860508
 $M_{Ro}$  (4.18) = 3.5813E+008
 $M_{Ro} < 0.8 \cdot M_{Rc}$ 
--->
 $u = \epsilon_{cu}$  (unconfined full section) = 1.6866617E-005
 $\mu = M_{Rc}$ 
-----

```

Calculation of ratio l_b/l_d

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

Calculation of Mu2-

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

$$\mu = 9.8367160E-006$$

$$\mu_u = 2.0582E+008$$

with full section properties:

$$b = 200.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$\nu = 1.27847$$

$$N = 1.5610E+006$$

$$f_c = 15.00$$

$$\alpha_1(5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.0035$$

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

$$\text{From (5.4b), TB DY: } \mu_u = 0.0035$$

$$\mu_{ue} \text{ (5.4c)} = 0.00$$

$$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

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

$$\mu_{sh,min} = \text{Min}(\mu_{sh,x}, \mu_{sh,y}) = 0.0019822$$

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

$$\mu_{sh,x} \text{ ((5.4d), TB DY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

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

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

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

$$\mu_{sh,y} \text{ ((5.4d), TB DY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

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

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

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

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

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

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

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

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

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

```

    with Es1 = Es = 200000.00
    y2 = 0.00231479
    sh2 = 0.008
    ft2 = 666.66
    fy2 = 555.55
    su2 = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/lb,min = 1.00
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
    with fs2 = fs = 555.55
    with Es2 = Es = 200000.00
    yv = 0.00231479
    shv = 0.008
    ftv = 666.66
    fyv = 555.55
    suv = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/ld = 1.00
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
    with fsv = fs = 555.55
    with Esv = Es = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.79475296
    2 = Asl,com/(b*d)*(fs2/fc) = 0.37736471
    v = Asl,mid/(b*d)*(fsv/fc) = 0.7032706
    and confined core properties:
    b = 140.00
    d = 377.00
    d' = 13.00
    fcc (5A.2, TBDY) = 15.00
    cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
    2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
    v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
    Case/Assumption: Unconfined full section - Steel rupture
    ' does not satisfy Eq. (4.3)
    --->
    v < vs,c - RHS eq.(4.5) is not satisfied
    --->
    Case/Assumption Rejected.
    --->
    New Case/Assumption: Unconfined full section - Spalling of concrete cover
    ' satisfies Eq. (4.4)
    --->
    v < sy1 - LHS eq.(4.7) is not satisfied
    --->
    v < vc,y1 - RHS eq.(4.6) is not satisfied
    --->
    cu (4.11) = 0.87422556
    MRc (4.18) = 2.0582E+008
    --->
    New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
    In expressions below, the following modifications have been made
    - b, d, d' replaced by geometric parameters of the core: bo, do, d'o

```

- N_1, N_2 v normalised to $b_o \cdot d_o$, instead of $b \cdot d$
- parameters of confined concrete, f_{cc}, ϵ_{cc} , used in lieu of f_c, ϵ_{cu}

--->

Subcase: Rupture of tension steel

--->

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

--->

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

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

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

--->

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

--->

$\epsilon_{cu} (4.11) = 1.00$

$M_{Ro} (4.18) = 1.2754E+008$

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

--->

$\epsilon_u = \epsilon_{cu}$ (unconfined full section) = $9.8367160E-006$

$\mu_u = \mu_{Rc}$

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 165623.448$

Calculation of Shear Strength at edge 1, $V_{r1} = 165623.448$

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

$V_{Col0} = 165623.448$

$k_n l = 1$ (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).

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

$f'_c = 15.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/V_d = 4.00$

$\mu_u = 1.4825E+008$

$V_u = 2.2161626E-006$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.5610E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$

where:

$V_{s1} = 55849.978$ is calculated for section web, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

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

$s/d = 0.83333333$

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

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

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

$s/d = 1.875$

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

From (11-11), ACI 440: $V_s + V_f \leq 185244.312$
 $bw = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 165623.448$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 165623.448$
 $knl = 1$ (zero step-static loading)

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

$= 1$ (normal-weight concrete)
 $f'_c = 15.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 1.2485E+008$
 $V_u = 2.2161626E-006$
 $d = 0.8 * h = 360.00$
 $N_u = 1.5610E+006$
 $A_g = 90000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$
where:
 $V_{s1} = 55849.978$ is calculated for section web, with:
 $d = 360.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 300.00$
 V_{s1} is multiplied by $Col1 = 0.66666667$
 $s/d = 0.83333333$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 160.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 300.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.875$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
From (11-11), ACI 440: $V_s + V_f \leq 185244.312$
 $bw = 200.00$

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

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

Constant Properties

Knowledge Factor, $= 1.00$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 15.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 18203.022$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, $f_s = 1.25 * f_{sm} = 555.55$

Max Height, $H_{max} = 450.00$

Min Height, $H_{min} = 200.00$
Max Width, $W_{max} = 450.00$
Min Width, $W_{min} = 200.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.00
Element Length, $L = 3000.00$
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou,min} \geq 1$)
No FRP Wrapping

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = -5.2893364E-006$
EDGE -B-
Shear Force, $V_b = 5.2893364E-006$
BOTH EDGES
Axial Force, $F = -1.5610E+006$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 716.2831$
-Compression: $As_c = 3091.327$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1746.726$
-Compression: $As_{c,com} = 829.3805$
-Middle: $As_{c,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.8353$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 303967.895$
with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 4.5595E+008$
 $\mu_{u1+} = 2.0582E+008$, 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
 $\mu_{u1-} = 4.5595E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 4.5595E+008$
 $\mu_{u2+} = 2.0582E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u2-} = 4.5595E+008$, 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_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 9.8367160E-006$
 $\mu_u = 2.0582E+008$

with full section properties:

$b = 200.00$
 $d = 407.00$
 $d' = 43.00$
 $v = 1.27847$
 $N = 1.5610E+006$
 $f_c = 15.00$
 $\alpha_1 (5A_s, TBDY) = 0.002$

Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0035$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $cu = 0.0035$
 we (5.4c) = 0.00
 $ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.00$
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.
 $A_{\text{conf,max}} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{\text{conf,min}} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max}}$ by a length equal to half the clear spacing between hoops.
 $A_{\text{noConf}} = 54733.333$ is the unconfined core area which is equal to $bi^2/6$ as defined at (A.2).
 $psh_{\text{min}} = \text{Min}(psh_x, psh_y) = 0.0019822$
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) = $L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.0019822$
 L_{stir} (Length of stirrups along Y) = 1060.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 140000.00

psh_y ((5.4d), TBDY) = $L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.0019822$
 L_{stir} (Length of stirrups along X) = 1060.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 140000.00

$s = 300.00$
 $fy_{we} = 555.55$
 $f_{ce} = 15.00$

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

$y1 = 0.00231479$
 $sh1 = 0.008$
 $ft1 = 666.66$
 $fy1 = 555.55$
 $su1 = 0.032$

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

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

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

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

with $fs1 = fs = 555.55$

with $Es1 = Es = 200000.00$

$y2 = 0.00231479$
 $sh2 = 0.008$
 $ft2 = 666.66$
 $fy2 = 555.55$
 $su2 = 0.032$

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

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

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

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

For calculation of $esu2_{\text{nominal}}$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

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

with $fs2 = fs = 555.55$

with $Es2 = Es = 200000.00$

```

yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/ld = 1.00
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
    with fsv = fs = 555.55
    with Esv = Es = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.79475296
    2 = Asl,com/(b*d)*(fs2/fc) = 0.37736471
    v = Asl,mid/(b*d)*(fsv/fc) = 0.7032706
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
    2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
    v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->

```

*cu (4.11) = 1.00
MRO (4.18) = 1.2754E+008
MRO < 0.8*MRc

--->
u = cu (unconfined full section) = 9.8367160E-006
Mu = MRc

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Mu1-

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

u = 1.6866617E-005
Mu = 4.5595E+008

with full section properties:

b = 450.00
d = 407.00
d' = 43.00
v = 0.5682084
N = 1.5610E+006
fc = 15.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.0035

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

From (5.4b), TBDY: cu = 0.0035

we (5.4c) = 0.00

ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.00

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

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

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

Aconf,max = 89600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

Aconf,min = 0.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 54733.333 is the unconfined core area which is equal to bi2/6 as defined at (A.2).

psh,min = Min(psh,x, psh,y) = 0.0019822

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) = 0.0019822

Lstir (Length of stirrups along Y) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.0019822

Lstir (Length of stirrups along X) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

s = 300.00

fywe = 555.55

fce = 15.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

```

ft1 = 666.66
fy1 = 555.55
su1 = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 1.00
    su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu1_nominal = 0.08,
    For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
    characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
    with fs1 = fs = 555.55
    with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 1.00
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
    with fs2 = fs = 555.55
    with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 1.00
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
    with fsv = fs = 555.55
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16771765
2 = Asl,com/(b*d)*(fs2/fc) = 0.35322354
v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
    2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
    v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->

```

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

--->
 $v < s, y1$ - LHS eq.(4.7) is not satisfied
--->
 $v < v_c, y1$ - RHS eq.(4.6) is satisfied
--->

c_u (4.10) = 0.5098538
 M_{Rc} (4.17) = 4.5595E+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, e_c
--->

Subcase: Rupture of tension steel

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

Subcase rejected

--->
New Subcase: Failure of compression zone

--->
 $v^* < v^* c, y2$ - LHS eq.(4.6) is not satisfied
--->
 $v^* < v^* c, y1$ - RHS eq.(4.6) is not satisfied
--->

$*c_u$ (4.11) = 0.56860508
 M_{Ro} (4.18) = 3.5813E+008
 $M_{Ro} < 0.8 * M_{Rc}$
--->

$u = c_u$ (unconfined full section) = 1.6866617E-005
 $M_u = M_{Rc}$

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:
 $u = 9.8367160E-006$
 $M_u = 2.0582E+008$

with full section properties:

$b = 200.00$
 $d = 407.00$
 $d' = 43.00$
 $v = 1.27847$
 $N = 1.5610E+006$
 $f_c = 15.00$
 c_o (5A.5, TBDY) = 0.002
Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0035$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $c_u = 0.0035$
 w_e (5.4c) = 0.00
 $a_s = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$
The definitions of $A_{\text{noConf}}, A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization
of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)
"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and
is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and
is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length
equal to half the clear spacing between hoops.

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

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.0019822$

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

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.0019822$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.0019822$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$s = 300.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

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

c = confinement factor = 1.00

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

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

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

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

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

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

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

with $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

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

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

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

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

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

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

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$su_v = 0.032$

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

```

Shear_factor = 1.00
lo/lou,min = lb/ld = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.79475296
2 = Asl,com/(b*d)*(fs2/fc) = 0.37736471
v = Asl,mid/(b*d)*(fsv/fc) = 0.7032706
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 9.8367160E-006
Mu = MRc
-----

```


Calculation of ratio l_b/d

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

Calculation of μ_u

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

$$\mu_u = 1.6866617E-005$$

$$\mu_u = 4.5595E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$\nu = 0.5682084$$

$$N = 1.5610E+006$$

$$f_c = 15.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \omega) = 0.0035$$

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

$$\text{From (5.4b), TB DY: } \mu_u = 0.0035$$

$$\omega (5.4c) = 0.00$$

$$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

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

$$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.0019822$$

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

$$\mu_{psh,x} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

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

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

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

$$\mu_{psh,y} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

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

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

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

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$f_{t1} = 666.66$$

$$f_{y1} = 555.55$$

$$su_1 = 0.032$$

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

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

```

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fs1 = fs = 555.55
with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16771765
2 = Asl,com/(b*d)*(fs2/fc) = 0.35322354
v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < s,y1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->

```

$\phi_{cu} (4.10) = 0.5098538$
 $M_{Rc} (4.17) = 4.5595E+008$
 --->
 New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
 In expressions below, the following modifications have been made
 - b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o
 - N_1, N_2, v normalised to b_o*d_o , instead of $b*d$
 - parameters of confined concrete, f_{cc}, ϵ_{cc} , used in lieu of f_c, ϵ_{cu}

Subcase: Rupture of tension steel

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

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

Subcase rejected

New Subcase: Failure of compression zone

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

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

$\phi_{cu} (4.11) = 0.56860508$

$M_{Ro} (4.18) = 3.5813E+008$

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

$u = \phi_{cu}$ (unconfined full section) = $1.6866617E-005$

$\mu = M_{Rc}$

Calculation of ratio l_b/l_d

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

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 165623.448$

Calculation of Shear Strength at edge 1, $V_{r1} = 165623.448$

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

$V_{ColO} = 165623.448$

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

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

$= 1$ (normal-weight concrete)
 $f'_c = 15.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.4432E+008$

$V_u = 5.2893364E-006$

$d = 0.8*h = 360.00$

$N_u = 1.5610E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$

where:

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

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

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

$s/d = 1.875$

$V_{s2} = 55849.978$ is calculated for section flange, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

V_{s2} is multiplied by $Col2 = 0.66666667$

$s/d = 0.83333333$

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

From (11-11), ACI 440: $V_s + V_f \leq 185244.312$

$b_w = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 165623.448$

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

$V_{Col0} = 165623.448$

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

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

$= 1$ (normal-weight concrete)

$f'_c = 15.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.2049E+008$

$\mu_u = 5.2893364E-006$

$d = 0.8 * h = 360.00$

$N_u = 1.5610E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$

where:

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

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

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

$s/d = 1.875$

$V_{s2} = 55849.978$ is calculated for section flange, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

V_{s2} is multiplied by $Col2 = 0.66666667$

$s/d = 0.83333333$

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

From (11-11), ACI 440: $V_s + V_f \leq 185244.312$

$b_w = 200.00$

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

At local axis: 2

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

At local axis: 2

Integration Section: (a)

Section Type: rdlcs

Constant Properties

Knowledge Factor, $= 1.00$

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

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

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 15.00$

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

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$
 Max Height, $H_{max} = 450.00$
 Min Height, $H_{min} = 200.00$
 Max Width, $W_{max} = 450.00$
 Min Width, $W_{min} = 200.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_b/d >= 1$)
 No FRP Wrapping

Stepwise Properties

Bending Moment, $M = -2.4005E+008$
 Shear Force, $V_2 = 114740.397$
 Shear Force, $V_3 = 0.02811617$
 Axial Force, $F = -1.5617E+006$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{st} = 1545.664$
 -Compression: $A_{sc} = 2576.106$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{st,ten} = 829.3805$
 -Compression: $A_{sc,com} = 1746.726$
 -Middle: $A_{st,mid} = 1545.664$
 Mean Diameter of Tension Reinforcement, $Db_L = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = \gamma + p = 0.02445758$

- Calculation of γ -

$\gamma = (M_y * L_s / 3) / E_{eff} = 0.02445758$ ((4.29), Biskinis Phd))
 $M_y = 3.4088E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 6000.00
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 2.7875E+013$
 factor = 0.70
 $A_g = 140000.00$
 $f_c' = 15.00$
 $N = 1.5617E+006$
 $E_c * I_g = 3.9822E+013$

Calculation of Yielding Moment M_y

Calculation of γ and M_y according to Annex 7 -

Assuming neutral axis out of flange ($\gamma > t/d$, compression zone NOT rectangular)
 extended expressions (2.1)-(2.7) of Biskinis-Fardis (2009) are adopted with:
 flange width, $b = 450.00$
 web width, $b_w = 200.00$
 flange thickness, $t = 200.00$

$\gamma = \text{Min}(\gamma_{ten}, \gamma_{com})$
 $\gamma_{ten} = 1.0245677E-005$
 with $f_y = 444.44$
 $d = 407.00$
 $\gamma = 0.46709713$

A = 0.1497109
B = 0.07985836
with pt = 0.0019822
pc = 0.00953713
pv = 0.00843933
N = 1.5617E+006
b = 450.00
" = 0.10565111
y_comp = 6.6398011E-006

with fc = 15.00
Ec = 18203.022
y = 0.54887164
A = 0.04186757
B = 0.03668953
with Es = 200000.00
CONFIRMATION: $y = 0.54887164 > t/d$

Calculation of ratio l_b/l_d

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

- Calculation of p -

From table 10-8: $p = 0.00$

with:

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

shear control ratio $V_y E / V_{col} O E = 1.8353$

d = 407.00

s = 100.00

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.0019822$

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

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

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

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

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

NUD = 1.5617E+006

$A_g = 140000.00$

$f_{cE} = 15.00$

$f_{ytE} = f_{yIE} = 444.44$

$p_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.02250488$

b = 450.00

d = 407.00

$f_{cE} = 15.00$

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

At local axis: 2

Integration Section: (a)

Calculation No. 3

column C1, Floor 1

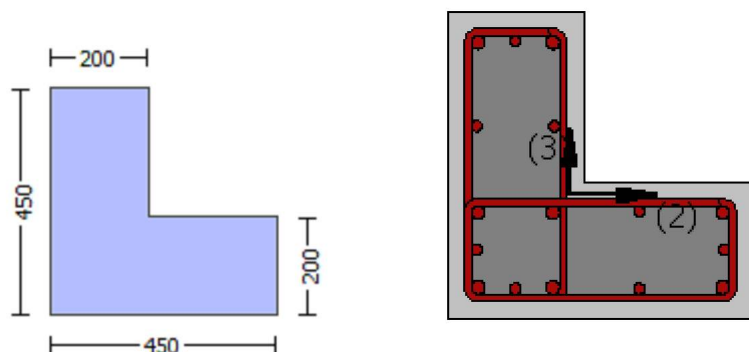
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



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

At local axis: 3

Integration Section: (a)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 10.00$

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

Concrete Elasticity, $E_c = 18203.022$

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

Existing material: Concrete Strength, $f_c = f_{cm} = 15.00$

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

#####

Max Height, $H_{max} = 450.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 450.00$

Min Width, $W_{min} = 200.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

No FRP Wrapping

Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = -2.4005E+008$
 Shear Force, $V_a = 0.02811617$
 EDGE -B-
 Bending Moment, $M_b = 1.2500E+008$
 Shear Force, $V_b = -0.02811617$
 BOTH EDGES
 Axial Force, $F = -1.5617E+006$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 1545.664$
 -Compression: $As_c = 2576.106$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{t,ten} = 829.3805$
 -Compression: $As_{c,com} = 1746.726$
 -Middle: $As_{mid} = 1545.664$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = V_n = 148562.593$
 V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{Col0} = 148562.593$
 $V_{Col} = 148562.593$
 $k_n = 1.00$
 $displacement_ductility_demand = 1.00493$

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

$\phi = 1$ (normal-weight concrete)
 $f'_c = 10.00$, but $f_c^{0.5} \leq 8.3$ MPa ((22.5.3.1, ACI 318-14))
 $M/Vd = 4.00$
 $M_u = 2.4005E+008$
 $V_u = 0.02811617$
 $d = 0.8 \cdot h = 360.00$
 $N_u = 1.5617E+006$
 $A_g = 90000.00$
 From ((11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 50265.482$
 where:
 $V_{s1} = 50265.482$ is calculated for section web, with:
 $d = 360.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 300.00$
 V_{s1} is multiplied by $Col1 = 0.66666667$
 $s/d = 0.83333333$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 160.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 300.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.875$
 V_f ((11-3)-(11.4), ACI 440) = 0.00
 From ((11-11), ACI 440: $V_s + V_f \leq 151251.347$
 $bw = 200.00$

$displacement_ductility_demand$ is calculated as ϕ / y

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

From analysis, chord rotation $\phi = 0.02457814$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.02445758$ ((4.29), Biskinis Phd))
 $M_y = 3.4088E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 6000.00
From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 2.7875E+013$
factor = 0.70
 $A_g = 140000.00$
 $f_c' = 15.00$
 $N = 1.5617E+006$
 $E_c \cdot I_g = 3.9822E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

Assuming neutral axis out of flange ($y > t/d$, compression zone NOT rectangular)
extended expressions (2.1)-(2.7) of Biskinis-Fardis (2009) are adopted with:
flange width, $b = 450.00$
web width, $b_w = 200.00$
flange thickness, $t = 200.00$

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 1.0245677E-005$
with $f_y = 444.44$
 $d = 407.00$
 $y = 0.46709713$
 $A = 0.1497109$
 $B = 0.07985836$
with $p_t = 0.00452842$
 $p_c = 0.00953713$
 $p_v = 0.00843933$
 $N = 1.5617E+006$
 $b = 450.00$
 $" = 0.10565111$
 $y_{comp} = 6.6398011E-006$
with $f_c = 15.00$
 $E_c = 18203.022$
 $y = 0.54887164$
 $A = 0.04186757$
 $B = 0.03668953$
with $E_s = 200000.00$
CONFIRMATION: $y = 0.54887164 > t/d$

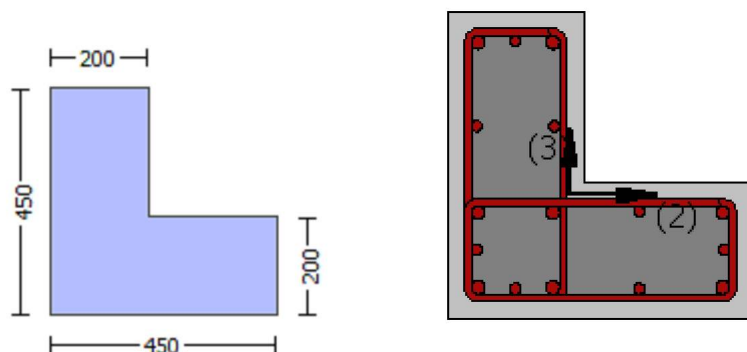
Calculation of ratio I_b/I_d

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

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

Calculation No. 4

column C1, Floor 1
 Limit State: Operational Level (data interpolation between analysis steps 50 and 51)
 Analysis: Uniform +X
 Check: Chord rotation capacity (ϕ)
 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, $f_c = f_{cm} = 15.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 18203.022$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$
 #####
 Max Height, $H_{max} = 450.00$
 Min Height, $H_{min} = 200.00$
 Max Width, $W_{max} = 450.00$
 Min Width, $W_{min} = 200.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.00
 Element Length, $L = 3000.00$
 Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{ou,min} \geq 1$)
 No FRP Wrapping

Stepwise Properties

At local axis: 3
 EDGE -A-

Shear Force, $V_a = 2.2161626E-006$

EDGE -B-

Shear Force, $V_b = -2.2161626E-006$

BOTH EDGES

Axial Force, $F = -1.5610E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 716.2831$

-Compression: $As_c = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

-Middle: $As_{mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.8353$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 303967.895$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 4.5595E+008$

$Mu_{1+} = 4.5595E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.0582E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 4.5595E+008$

$Mu_{2+} = 4.5595E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.0582E+008$, 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:

$\phi_u = 1.6866617E-005$

$M_u = 4.5595E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.5682084$

$N = 1.5610E+006$

$f_c = 15.00$

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

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0035$

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

From (5.4b), TBDY: $\phi_u = 0.0035$

$\phi_{we} (5.4c) = 0.00$

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.00$

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

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

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

$\phi_{psh,min} = \text{Min}(\phi_{psh,x}, \phi_{psh,y}) = 0.0019822$

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

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.0019822$$

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

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

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

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.0019822$$

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

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

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

$$s = 300.00$$

$$fywe = 555.55$$

$$fce = 15.00$$

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

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

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

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

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

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

$$\text{From table 5A.1, TBDY: } esu1_nominal = 0.08,$$

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

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

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

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

$$y2 = 0.00231479$$

$$sh2 = 0.008$$

$$ft2 = 666.66$$

$$fy2 = 555.55$$

$$su2 = 0.032$$

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

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

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

$$\text{From table 5A.1, TBDY: } esu2_nominal = 0.08,$$

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

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

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

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

$$yv = 0.00231479$$

$$shv = 0.008$$

$$ftv = 666.66$$

$$fyv = 555.55$$

$$suv = 0.032$$

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

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

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

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

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

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

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

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

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.16771765$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.35322354$$

```

v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < s,y1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.5098538
MRc (4.17) = 4.5595E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
--->
v* < v*s,c - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
--->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
--->
*cu (4.11) = 0.56860508
MRo (4.18) = 3.5813E+008
MRo < 0.8*MRc
--->
u = cu (unconfined full section) = 1.6866617E-005
Mu = MRc

```

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 = 9.8367160E-006
Mu = 2.0582E+008

with full section properties:

b = 200.00
d = 407.00
d' = 43.00
v = 1.27847
N = 1.5610E+006

fc = 15.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.0035

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

From (5.4b), TBDY: cu = 0.0035

we (5.4c) = 0.00

ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.00

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

Aconf,max = 89600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

Aconf,min = 0.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 54733.333 is the unconfined core area which is equal to bi2/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.0019822

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) = 0.0019822

Lstir (Length of stirrups along Y) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.0019822

Lstir (Length of stirrups along X) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

s = 300.00

fywe = 555.55

fce = 15.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

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

lo/lou,min = lb/d = 1.00

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

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

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

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

```

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/d = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.79475296
2 = Asl,com/(b*d)*(fs2/fc) = 0.37736471
v = Asl,mid/(b*d)*(fsv/fc) = 0.7032706
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+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*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 9.8367160E-006
Mu = MRc
-----

Calculation of ratio lb/ld
-----
Adequate Lap Length: lb/ld >= 1
-----
-----
Calculation of Mu2+
-----
-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.6866617E-005
Mu = 4.5595E+008
-----

with full section properties:
b = 450.00
d = 407.00
d' = 43.00
v = 0.5682084
N = 1.5610E+006
fc = 15.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.0035
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.0035
we (5.4c) = 0.00
ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.00
The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization
of the rectangular sections confinement, which is expressed by (5.4d).
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)
"Theoretical Stress-Strain Model for Confined Concrete."
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
Aconf,max = 89600.00 is the confined core area at levels of member with hoops and
is calculated as the area of core enclosed by the center lines of the perimeter hoops.
Aconf,min = 0.00 is the confined core area at midway between the levels of hoops and
is calculated by reducing all the dimensions of the area Aconf,max by a length
equal to half the clear spacing between hoops.
AnoConf = 54733.333 is the unconfined core area which is equal to bi2/6 as defined at (A.2).
psh,min = Min(psh,x , psh,y) = 0.0019822
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) = 0.0019822
Lstir (Length of stirrups along Y) = 1060.00
Astir (stirrups area) = 78.53982
Asec (section area) = 140000.00
-----
psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.0019822

```


Lstir (Length of stirrups along X) = 1060.00
Astir (stirrups area) = 78.53982
Asec (section area) = 140000.00

s = 300.00

fywe = 555.55

fce = 15.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

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

lo/lou,min = lb/lb = 1.00

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

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

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

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

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

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

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

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

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

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

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

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

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

lo/lou,min = lb/lb = 1.00

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

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

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

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

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

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16771765

2 = Asl,com/(b*d)*(fs2/fc) = 0.35322354

v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471

and confined core properties:

b = 390.00

d = 377.00

d' = 13.00

fcc (5A.2, TBDY) = 15.00

cc (5A.5, TBDY) = 0.002

```

c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.5098538
MRc (4.17) = 4.5595E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
--->
v* < v*sc - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
--->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
--->
*cu (4.11) = 0.56860508
MRo (4.18) = 3.5813E+008
MRo < 0.8*MRc
--->
u = cu (unconfined full section) = 1.6866617E-005
Mu = MRc
-----

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

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

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 9.8367160E-006
Mu = 2.0582E+008
-----

with full section properties:
b = 200.00
d = 407.00
d' = 43.00

```

$v = 1.27847$
 $N = 1.5610E+006$
 $f_c = 15.00$
 $\alpha (5A.5, TBDY) = 0.002$
 Final value of α : $\alpha = \text{shear_factor} * \text{Max}(\alpha_c, \alpha_s) = 0.0035$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\alpha_c = 0.0035$
 $\alpha_s (5.4c) = 0.00$
 $\alpha_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$
 The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
 $A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.
 $A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $\alpha_{sh,min} = \text{Min}(\alpha_{sh,x}, \alpha_{sh,y}) = 0.0019822$
 Expression ((5.4d), TBDY) for $\alpha_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\alpha_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$
 L_{stir} (Length of stirrups along Y) = 1060.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 140000.00

$\alpha_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$
 L_{stir} (Length of stirrups along X) = 1060.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 140000.00

$s = 300.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 15.00$
 From ((5.A5), TBDY), TBDY: $\alpha_c = 0.002$
 α_c = confinement factor = 1.00
 $y_1 = 0.00231479$
 $sh_1 = 0.008$
 $ft_1 = 666.66$
 $fy_1 = 555.55$
 $su_1 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $su_1 = 0.4 * \alpha_{su1_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $\alpha_{su1_nominal} = 0.08$,
 For calculation of $\alpha_{su1_nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = f_s/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_1 = f_s = 555.55$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.00231479$
 $sh_2 = 0.008$
 $ft_2 = 666.66$
 $fy_2 = 555.55$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$
 $su_2 = 0.4 * \alpha_{su2_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $\alpha_{su2_nominal} = 0.08$,
 For calculation of $\alpha_{su2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered

characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
with $f_{s2} = f_s = 555.55$
with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00231479$
 $sh_v = 0.008$
 $ft_v = 666.66$
 $f_{y_v} = 555.55$
 $s_{u_v} = 0.032$
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
 $l_o/l_{o,min} = l_b/l_d = 1.00$
 $s_{u_v} = 0.4 \cdot e_{s_{u_v,nominal}} ((5.5), \text{TBDY}) = 0.032$
From table 5A.1, TBDY: $e_{s_{u_v,nominal}} = 0.08$,
considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY
For calculation of $e_{s_{u_v,nominal}}$ and y_v, sh_v, ft_v, f_{y_v} , it is considered
characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
with $f_{sv} = f_s = 555.55$
with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.79475296$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.37736471$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.7032706$
and confined core properties:
 $b = 140.00$
 $d = 377.00$
 $d' = 13.00$
 $f_{cc} (5A.2, \text{TBDY}) = 15.00$
 $cc (5A.5, \text{TBDY}) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 1.22571$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.58199105$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 1.08462$
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
 $v < v_{s,c}$ - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
 $v < s_{y1}$ - LHS eq.(4.7) is not satisfied
--->
 $v < v_{c,y1}$ - RHS eq.(4.6) is not satisfied
--->
 $cu (4.11) = 0.87422556$
 $M_{Rc} (4.18) = 2.0582E+008$
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o
- $N, 1, 2, v$ normalised to $b_o \cdot d_o$, instead of $b \cdot d$
- f_{cc}, cc parameters of confined concrete, f_{cc}, cc , used in lieu of f_c, e_{cu}
--->
Subcase: Rupture of tension steel
--->
 $v^* < v^* s_{y2}$ - LHS eq.(4.5) is not satisfied
--->
 $v^* < v^* s_{c}$ - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->

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

--->

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

--->

$*c_u (4.11) = 1.00$

$M_{Ro} (4.18) = 1.2754E+008$

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

--->

$u = c_u$ (unconfined full section) = $9.8367160E-006$

$\mu = M_{Rc}$

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 165623.448$

Calculation of Shear Strength at edge 1, $V_{r1} = 165623.448$

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

$V_{ColO} = 165623.448$

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

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

$= 1$ (normal-weight concrete)

$f'_c = 15.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.4825E+008$

$V_u = 2.2161626E-006$

$d = 0.8*h = 360.00$

$N_u = 1.5610E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$

where:

$V_{s1} = 55849.978$ is calculated for section web, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

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

$s/d = 0.83333333$

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

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

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

$s/d = 1.875$

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

From (11-11), ACI 440: $V_s + V_f \leq 185244.312$

$b_w = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 165623.448$

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

$V_{ColO} = 165623.448$

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

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

$= 1$ (normal-weight concrete)

```

fc' = 15.00, but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 1.2485E+008
Vu = 2.2161626E-006
d = 0.8*h = 360.00
Nu = 1.5610E+006
Ag = 90000.00
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 55849.978$ 
where:
Vs1 = 55849.978 is calculated for section web, with:
d = 360.00
Av = 157079.633
fy = 444.44
s = 300.00
Vs1 is multiplied by Col1 = 0.66666667
s/d = 0.83333333
Vs2 = 0.00 is calculated for section flange, with:
d = 160.00
Av = 157079.633
fy = 444.44
s = 300.00
Vs2 is multiplied by Col2 = 0.00
s/d = 1.875
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440:  $V_s + V_f \leq 185244.312$ 
bw = 200.00
-----

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

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

Constant Properties
-----
Knowledge Factor,  $\phi = 1.00$ 
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 15.00$ 
Existing material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 444.44$ 
Concrete Elasticity,  $E_c = 18203.022$ 
Steel Elasticity,  $E_s = 200000.00$ 
#####
Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength,  $f_s = 1.25*f_{sm} = 555.55$ 
#####
Max Height,  $H_{max} = 450.00$ 
Min Height,  $H_{min} = 200.00$ 
Max Width,  $W_{max} = 450.00$ 
Min Width,  $W_{min} = 200.00$ 
Cover Thickness,  $c = 25.00$ 
Mean Confinement Factor overall section = 1.00
Element Length,  $L = 3000.00$ 
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ( $l_o/l_{ou,min} \geq 1$ )
No FRP Wrapping

```

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = -5.2893364E-006$

EDGE -B-

Shear Force, $V_b = 5.2893364E-006$

BOTH EDGES

Axial Force, $F = -1.5610E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 716.2831$

-Compression: $As_c = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Calculation of Shear Capacity ratio, $V_e/V_r = 1.8353$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 303967.895$
with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 4.5595E+008$

$Mu_{1+} = 2.0582E+008$, 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

$Mu_{1-} = 4.5595E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 4.5595E+008$

$Mu_{2+} = 2.0582E+008$, 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

$Mu_{2-} = 4.5595E+008$, 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:

$\phi_u = 9.8367160E-006$

$M_u = 2.0582E+008$

with full section properties:

$b = 200.00$

$d = 407.00$

$d' = 43.00$

$v = 1.27847$

$N = 1.5610E+006$

$f_c = 15.00$

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

Final value of ϕ_{cu} : $\phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.0035$

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

From (5.4b), TBDY: $\phi_{cu} = 0.0035$

$\phi_{we} (5.4c) = 0.00$

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.00$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and

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

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

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

psh,min = Min(psh,x , psh,y) = 0.0019822

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) = 0.0019822

Lstir (Length of stirrups along Y) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.0019822

Lstir (Length of stirrups along X) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

s = 300.00

fywe = 555.55

fce = 15.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

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

lo/lou,min = lb/lb = 1.00

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

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

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

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

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

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

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

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

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

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

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

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

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

lo/lou,min = lb/lb = 1.00

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

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

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


```

characteristic value  $f_{sv} = f_{sv}/1.2$ , 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, ASCE 41-17.
with  $f_{sv} = f_s = 555.55$ 
with  $E_{sv} = E_s = 200000.00$ 
1 =  $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.79475296$ 
2 =  $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.37736471$ 
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.7032706$ 
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 =  $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 1.22571$ 
2 =  $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.58199105$ 
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 1.08462$ 
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
 $v < v_{s,c}$  - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
 $v < s_{y1}$  - LHS eq.(4.7) is not satisfied
--->
 $v < v_{c,y1}$  - RHS eq.(4.6) is not satisfied
--->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core:  $b_o, d_o, d'_o$ 
-  $N_1, N_2, v$  normalised to  $b_o \cdot d_o$ , instead of  $b \cdot d$ 
- parameters of confined concrete, fcc, cc, used in lieu of  $f_c, e_{cu}$ 
--->
Subcase: Rupture of tension steel
--->
 $v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied
--->
 $v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
 $v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied
--->
 $v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied
--->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008
MRo < 0.8*MRc
--->
u = cu (unconfined full section) = 9.8367160E-006
Mu = MRc
-----

```

Calculation of ratio l_b/l_d

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

Calculation of Mu1-

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

$$\mu = 1.6866617E-005$$

$$\mu_u = 4.5595E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.5682084$$

$$N = 1.5610E+006$$

$$f_c = 15.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, c_o) = 0.0035$$

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

$$\text{From (5.4b), TB DY: } \mu_u = 0.0035$$

$$\mu_{ue} (5.4c) = 0.00$$

$$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

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

$$\mu_{sh,min} = \text{Min}(\mu_{sh,x}, \mu_{sh,y}) = 0.0019822$$

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

$$\mu_{sh,x} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

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

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

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

$$\mu_{sh,y} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

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

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

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

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

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

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

For calculation of $esu_1_{nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TB DY.

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

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

```

    with Es1 = Es = 200000.00
    y2 = 0.00231479
    sh2 = 0.008
    ft2 = 666.66
    fy2 = 555.55
    su2 = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/lb,min = 1.00
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
    with fs2 = fs = 555.55
    with Es2 = Es = 200000.00
    yv = 0.00231479
    shv = 0.008
    ftv = 666.66
    fyv = 555.55
    suv = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/ld = 1.00
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
    with fsv = fs = 555.55
    with Esv = Es = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.16771765
    2 = Asl,com/(b*d)*(fs2/fc) = 0.35322354
    v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
    and confined core properties:
    b = 390.00
    d = 377.00
    d' = 13.00
    fcc (5A.2, TBDY) = 15.00
    cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
    2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
    v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
    Case/Assumption: Unconfined full section - Steel rupture
    ' does not satisfy Eq. (4.3)
    --->
    v < vs,c - RHS eq.(4.5) is not satisfied
    --->
    Case/Assumption Rejected.
    --->
    New Case/Assumption: Unconfined full section - Spalling of concrete cover
    ' satisfies Eq. (4.4)
    --->
    v < sy1 - LHS eq.(4.7) is not satisfied
    --->
    v < vc,y1 - RHS eq.(4.6) is satisfied
    --->
    cu (4.10) = 0.5098538
    MRc (4.17) = 4.5595E+008
    --->
    New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
    In expressions below, the following modifications have been made
    - b, d, d' replaced by geometric parameters of the core: bo, do, d'o

```

- N_1, N_2 v normalised to $b_o \cdot d_o$, instead of $b \cdot d$
- parameters of confined concrete, f_{cc} , ϵ_{cc} , used in lieu of f_c , ϵ_{cu}

---->

Subcase: Rupture of tension steel

---->

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

---->

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

---->

Subcase rejected

---->

New Subcase: Failure of compression zone

---->

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

---->

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

---->

ϵ^*_{cu} (4.11) = 0.56860508

M_{Ro} (4.18) = 3.5813E+008

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

---->

ϵ_u = ϵ_{cu} (unconfined full section) = 1.6866617E-005

$\mu_u = \mu_{Rc}$

Calculation of ratio I_b/I_d

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

Calculation of μ_{u2+}

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

$\epsilon_u = 9.8367160E-006$

$\mu_u = 2.0582E+008$

with full section properties:

$b = 200.00$

$d = 407.00$

$d' = 43.00$

$v = 1.27847$

$N = 1.5610E+006$

$f_c = 15.00$

ϵ_{co} (5A.5, TBDY) = 0.002

Final value of ϵ_{cu} : $\epsilon_{cu}^* = \text{shear_factor} \cdot \text{Max}(\epsilon_{cu}, \epsilon_{cc}) = 0.0035$

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

From (5.4b), TBDY: $\epsilon_{cu} = 0.0035$

ϵ_{we} (5.4c) = 0.00

$\epsilon_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.00$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

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

$\epsilon_{psh,min} = \text{Min}(\epsilon_{psh,x}, \epsilon_{psh,y}) = 0.0019822$

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

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.0019822$$

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

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

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

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.0019822$$

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

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

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

$$s = 300.00$$

$$fywe = 555.55$$

$$fce = 15.00$$

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

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

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

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

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

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

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

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

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

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

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

$$y2 = 0.00231479$$

$$sh2 = 0.008$$

$$ft2 = 666.66$$

$$fy2 = 555.55$$

$$su2 = 0.032$$

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

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

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

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

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

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

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

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

$$yv = 0.00231479$$

$$shv = 0.008$$

$$ftv = 666.66$$

$$fyv = 555.55$$

$$suv = 0.032$$

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

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

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

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

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

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

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

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

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.79475296$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.37736471$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.7032706$$

```

and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 9.8367160E-006
Mu = MRc

```

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

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

u = 1.6866617E-005

$$\mu = 4.5595E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.5682084$$

$$N = 1.5610E+006$$

$$f_c = 15.00$$

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

$$\text{Final value of } \phi: \phi^* = \text{shear_factor} * \text{Max}(\phi, \phi_c) = 0.0035$$

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

$$\text{From (5.4b), TB DY: } \phi = 0.0035$$

$$\phi_w (5.4c) = 0.00$$

$$\phi_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

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

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.0019822$$

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

$$\phi_{sh,x} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

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

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

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

$$\phi_{sh,y} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

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

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

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

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

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

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

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

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

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

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

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

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

and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 1.00$
 $\phi_{su2} = 0.4 \cdot \phi_{su2,nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $\phi_{su2,nominal} = 0.08$,
For calculation of $\phi_{su2,nominal}$ and ϕ_{y2} , ϕ_{sh2} , ϕ_{ft2} , ϕ_{fy2} , it is considered
characteristic value $\phi_{sy2} = \phi_{s2}/1.2$, from table 5.1, TBDY.
 ϕ_{y1} , ϕ_{sh1} , ϕ_{ft1} , ϕ_{fy1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
with $\phi_{s2} = \phi_s = 555.55$
with $E_{s2} = E_s = 200000.00$
 $\phi_{yv} = 0.00231479$
 $\phi_{shv} = 0.008$
 $\phi_{ftv} = 666.66$
 $\phi_{fyv} = 555.55$
 $\phi_{suv} = 0.032$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 1.00$
 $\phi_{suv} = 0.4 \cdot \phi_{suv,nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $\phi_{suv,nominal} = 0.08$,
considering characteristic value $\phi_{syv} = \phi_{sv}/1.2$, from table 5.1, TBDY
For calculation of $\phi_{suv,nominal}$ and ϕ_{yv} , ϕ_{shv} , ϕ_{ftv} , ϕ_{fyv} , it is considered
characteristic value $\phi_{syv} = \phi_{sv}/1.2$, from table 5.1, TBDY.
 ϕ_{y1} , ϕ_{sh1} , ϕ_{ft1} , ϕ_{fy1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
with $\phi_{sv} = \phi_s = 555.55$
with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (\phi_{s1}/\phi_c) = 0.16771765$
 $2 = A_{sl,com}/(b \cdot d) \cdot (\phi_{s2}/\phi_c) = 0.35322354$
 $v = A_{sl,mid}/(b \cdot d) \cdot (\phi_{sv}/\phi_c) = 0.31256471$
and confined core properties:
 $b = 390.00$
 $d = 377.00$
 $d' = 13.00$
 $\phi_{cc} (5A.2, TBDY) = 15.00$
 $\phi_{cc} (5A.5, TBDY) = 0.002$
 $\phi_c = \text{confinement factor} = 1.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (\phi_{s1}/\phi_c) = 0.20891986$
 $2 = A_{sl,com}/(b \cdot d) \cdot (\phi_{s2}/\phi_c) = 0.4399979$
 $v = A_{sl,mid}/(b \cdot d) \cdot (\phi_{sv}/\phi_c) = 0.38935066$
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
 $v < v_{s,c}$ - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
 $v < s_{y1}$ - LHS eq.(4.7) is not satisfied
--->
 $v < v_{c,y1}$ - RHS eq.(4.6) is satisfied
--->
 $\phi_{cu} (4.10) = 0.5098538$
 $M_{Rc} (4.17) = 4.5595E+008$
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b , d , d' replaced by geometric parameters of the core: b_o , d_o , d'_o
- N_1 , N_2 , v normalised to $b_o \cdot d_o$, instead of $b \cdot d$
- parameters of confined concrete, ϕ_{cc} , ϕ_c , used in lieu of ϕ_c , ϕ_{cu}
--->
Subcase: Rupture of tension steel
--->
 $v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied
--->

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

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

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

--->

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

--->

ϕ_{cu} (4.11) = 0.56860508

M_{Ro} (4.18) = 3.5813E+008

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

--->

$u = \phi_{cu}$ (unconfined full section) = 1.6866617E-005

$\mu_u = M_{Rc}$

Calculation of ratio l_b/l_d

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

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 165623.448$

Calculation of Shear Strength at edge 1, $V_{r1} = 165623.448$

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

$V_{ColO} = 165623.448$

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

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).

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

$f'_c = 15.00$, but $f'_c^{0.5} \leq 8.3$ MPa ((22.5.3.1), ACI 318-14)

$M/V_d = 4.00$

$\mu_u = 1.4432E+008$

$V_u = 5.2893364E-006$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.5610E+006$

$A_g = 90000.00$

From ((11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$

where:

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

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

V_{s1} is multiplied by $\phi_{col1} = 0.00$

$s/d = 1.875$

$V_{s2} = 55849.978$ is calculated for section flange, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

V_{s2} is multiplied by $\phi_{col2} = 0.66666667$

$s/d = 0.83333333$

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

From ((11-11), ACI 440: $V_s + V_f \leq 185244.312$

$b_w = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 165623.448$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l \cdot V_{ColO}$

$V_{ColO} = 165623.448$

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' = 15.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 1.2049E+008

Vu = 5.2893364E-006

d = 0.8*h = 360.00

Nu = 1.5610E+006

Ag = 90000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 55849.978

where:

Vs1 = 0.00 is calculated for section web, with:

d = 160.00

Av = 157079.633

fy = 444.44

s = 300.00

Vs1 is multiplied by Col1 = 0.00

s/d = 1.875

Vs2 = 55849.978 is calculated for section flange, with:

d = 360.00

Av = 157079.633

fy = 444.44

s = 300.00

Vs2 is multiplied by Col2 = 0.66666667

s/d = 0.83333333

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

From (11-11), ACI 440: Vs + Vf <= 185244.312

bw = 200.00

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

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

Constant Properties

Knowledge Factor, = 1.00

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

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

Consequently:

Existing material of Secondary Member: Concrete Strength, fc = fcm = 15.00

Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44

Concrete Elasticity, Ec = 18203.022

Steel Elasticity, Es = 200000.00

Max Height, Hmax = 450.00

Min Height, Hmin = 200.00

Max Width, Wmax = 450.00

Min Width, Wmin = 200.00

Cover Thickness, c = 25.00

Element Length, L = 3000.00

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($lb/d \geq 1$)

No FRP Wrapping

Stepwise Properties

Bending Moment, $M = -7.6058E+007$

Shear Force, $V2 = 114740.397$

Shear Force, $V3 = 0.02811617$

Axial Force, $F = -1.5617E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_{lt} = 1545.664$

-Compression: $As_{lc} = 2576.106$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Mean Diameter of Tension Reinforcement, $DbL = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{R} = u = 0.00116971$

$u = y + p = 0.00116971$

- Calculation of y -

$y = (M \cdot L_s / 3) / E_{eff} = 0.00116971$ ((4.29), Biskinis Phd))

$M_y = 1.4757E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 662.8737

From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 2.7875E+013$

factor = 0.70

$A_g = 140000.00$

$f_c' = 15.00$

$N = 1.5617E+006$

$E_c \cdot I_g = 3.9822E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$y_{ten} = 1.4507672E-005$

with $f_y = 444.44$

$d = 407.00$

$y = 0.62365079$

$A = 0.09380482$

$B = 0.07620117$

with $p_t = 0.0019822$

$p_c = 0.01018895$

$p_v = 0.0189885$

$N = 1.5617E+006$

$b = 200.00$

$\rho = 0.10565111$

$y_{comp} = 3.5726923E-006$

with $f_c = 15.00$

$E_c = 18203.022$

$y = 1.02007$

$A = -0.01403851$

$B = 0.03303234$

with $E_s = 200000.00$

Calculation of ratio I_b/I_d

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

- Calculation of ρ -

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

with:

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

shear control ratio $V_yE/V_{ColOE} = 1.8353$

$d = 407.00$

$s = 100.00$

$t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.0019822$

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

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

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

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

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

$NUD = 1.5617E+006$

$A_g = 140000.00$

$f_{cE} = 15.00$

$f_{ytE} = f_{ylE} = 444.44$

$\rho_l = \text{Area_Tot_Long_Rein}/(b*d) = 0.05063599$

$b = 200.00$

$d = 407.00$

$f_{cE} = 15.00$

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

At local axis: 3

Integration Section: (a)

Calculation No. 5

column C1, Floor 1

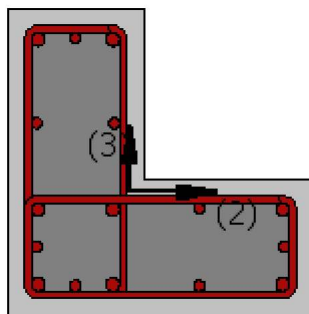
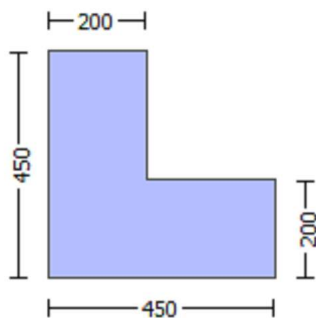
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (2)



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

At local axis: 2

Integration Section: (b)

Section Type: rcls

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 10.00$

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

Concrete Elasticity, $E_c = 18203.022$

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

Existing material: Concrete Strength, $f_c = f_{cm} = 15.00$

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

#####

Max Height, $H_{max} = 450.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 450.00$

Min Width, $W_{min} = 200.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

No FRP Wrapping

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -7.6058E+007$

Shear Force, $V_a = 114740.397$

EDGE -B-

Bending Moment, $M_b = 1.4356E+008$

Shear Force, $V_b = -114740.397$

BOTH EDGES

Axial Force, $F = -1.5617E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 1030.442$

-Compression: $As_c = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

-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 $V_R = V_n = 163021.761$

V_n ((10.3), ASCE 41-17) = $k_n I V_{CoIO} = 163021.761$

$V_{CoI} = 163396.885$

$k_n I = 0.99770422$

displacement_ductility_demand = 2.03061

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)

$f'_c = 10.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/V_d = 3.4755$

$M_u = 1.4356E+008$

$V_u = 114740.397$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.5617E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 50265.482$

where:

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

$d = 160.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 300.00$

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

$s/d = 1.875$

$V_{s2} = 50265.482$ is calculated for section flange, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 300.00$

V_{s2} is multiplied by $Col2 = 0.66666667$

$s/d = 0.83333333$

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

From (11-11), ACI 440: $V_s + V_f \leq 151251.347$

$b_w = 200.00$

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 $\phi = 0.00448326$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00220784$ ((4.29), Biskinis Phd))

$M_y = 1.4757E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1251.181

From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 2.7875E+013$

factor = 0.70

$A_g = 140000.00$

$f'_c = 15.00$

$N = 1.5617E+006$

$E_c \cdot I_g = 3.9822E+013$

Calculation of Yielding Moment M_y

Calculation of ϕ and M_y according to Annex 7 -

```

y = Min( y_ten, y_com)
y_ten = 1.4507672E-005
with fy = 444.44
d = 407.00
y = 0.62365079
A = 0.09380482
B = 0.07620117
with pt = 0.02145854
pc = 0.01018895
pv = 0.0189885
N = 1.5617E+006
b = 200.00
" = 0.10565111
y_comp = 3.5726923E-006
with fc = 15.00
Ec = 18203.022
y = 1.02007
A = -0.01403851
B = 0.03303234
with Es = 200000.00

```

Calculation of ratio I_b/I_d

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

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

At local axis: 2

Integration Section: (b)

Calculation No. 6

column C1, Floor 1

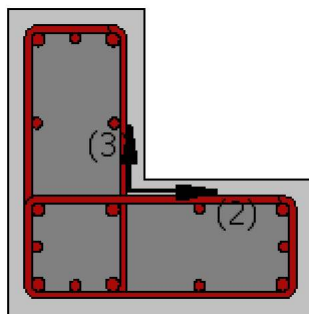
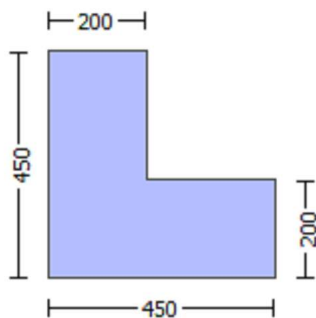
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

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: rccls

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 15.00$

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

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height, $H_{max} = 450.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 450.00$

Min Width, $W_{min} = 200.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

No FRP Wrapping

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 2.2161626E-006$

EDGE -B-

Shear Force, $V_b = -2.2161626E-006$

BOTH EDGES

Axial Force, $F = -1.5610E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 716.2831$

-Compression: $As_c = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Calculation of Shear Capacity ratio , $V_e/V_r = 1.8353$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 303967.895$
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 4.5595\text{E}+008$

$\mu_{1+} = 4.5595\text{E}+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{1-} = 2.0582\text{E}+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 4.5595\text{E}+008$

$\mu_{2+} = 4.5595\text{E}+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 2.0582\text{E}+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of μ_{1+}

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

$\mu = 1.6866617\text{E}-005$

$M_u = 4.5595\text{E}+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.5682084$

$N = 1.5610\text{E}+006$

$f_c = 15.00$

ϕ_c (5A.5, TBDY) = 0.002

Final value of ϕ_{cu} : $\phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_c) = 0.0035$

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

From (5.4b), TBDY: $\phi_{cu} = 0.0035$

ϕ_{we} (5.4c) = 0.00

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.00$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and

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

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and

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

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

$\phi_{psh,min} = \text{Min}(\phi_{psh,x}, \phi_{psh,y}) = 0.0019822$

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

$\phi_{psh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$\phi_{psh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$s = 300.00$

$f_{ywe} = 555.55$

```

fce = 15.00
From ((5A.5), TBDY), TBDY:  $c = 0.002$ 
 $c$  = 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
 $lo/lou,min = lb/ld = 1.00$ 
 $su_1 = 0.4 * esu1\_nominal ((5.5), TBDY) = 0.032$ 
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  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.
with  $fs_1 = fs = 555.55$ 
with  $Es_1 = Es = 200000.00$ 
 $y_2 = 0.00231479$ 
 $sh_2 = 0.008$ 
 $ft_2 = 666.66$ 
 $fy_2 = 555.55$ 
 $su_2 = 0.032$ 
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $lo/lou,min = lb/lb,min = 1.00$ 
 $su_2 = 0.4 * esu2\_nominal ((5.5), TBDY) = 0.032$ 
From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,
For calculation of  $esu2\_nominal$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered
characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.
with  $fs_2 = fs = 555.55$ 
with  $Es_2 = Es = 200000.00$ 
 $y_v = 0.00231479$ 
 $sh_v = 0.008$ 
 $ft_v = 666.66$ 
 $fy_v = 555.55$ 
 $suv = 0.032$ 
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
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  $y_v, sh_v, ft_v, fy_v$ , it is considered
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.
with  $fsv = fs = 555.55$ 
with  $Esv = Es = 200000.00$ 
 $1 = Asl,ten/(b*d)*(fs_1/fc) = 0.16771765$ 
 $2 = Asl,com/(b*d)*(fs_2/fc) = 0.35322354$ 
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471$ 
and confined core properties:
 $b = 390.00$ 
 $d = 377.00$ 
 $d' = 13.00$ 
 $f_{cc} (5A.2, TBDY) = 15.00$ 
 $cc (5A.5, TBDY) = 0.002$ 
 $c$  = confinement factor = 1.00
 $1 = Asl,ten/(b*d)*(fs_1/fc) = 0.20891986$ 
 $2 = Asl,com/(b*d)*(fs_2/fc) = 0.4399979$ 
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066$ 
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)

```

```

---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
'satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.5098538
MRc (4.17) = 4.5595E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N1, N2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.56860508
MRo (4.18) = 3.5813E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 1.6866617E-005
Mu = MRc

```

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 = 9.8367160E-006

Mu = 2.0582E+008

with full section properties:

```

b = 200.00
d = 407.00
d' = 43.00
v = 1.27847
N = 1.5610E+006
fc = 15.00
co (5A.5, TBDY) = 0.002
Final value of cu* = shear_factor * Max( cu, cc) = 0.0035
The Shear_factor is considered equal to 1 (pure moment strength)

```

From (5.4b), TBDY: $c_u = 0.0035$

w_e (5.4c) = 0.00

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

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

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.0019822$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$s = 300.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

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

c = confinement factor = 1.00

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

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

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

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

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

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

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

with $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

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

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

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

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

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

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

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

```

ftv = 666.66
fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/ld = 1.00
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
    with fsv = fs = 555.55
    with Esv = Es = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.79475296
    2 = Asl,com/(b*d)*(fs2/fc) = 0.37736471
    v = Asl,mid/(b*d)*(fsv/fc) = 0.7032706
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
    2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
    v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008

```

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

---->

$$u = c_u \text{ (unconfined full section)} = 9.8367160E-006$$

$$M_u = M_{Rc}$$

Calculation of ratio l_b/l_d

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

Calculation of M_{u2+}

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

$$\phi_u = 1.6866617E-005$$

$$M_u = 4.5595E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.5682084$$

$$N = 1.5610E+006$$

$$f_c = 15.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} \cdot \text{Max}(c_u, c_c) = 0.0035$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0035$$

$$w_e \text{ (5.4c)} = 0.00$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

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

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.0019822$$

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

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.0019822$$

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

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

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

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.0019822$$

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

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

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

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$f_{t1} = 666.66$$

$$f_{y1} = 555.55$$

```

su1 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/d = 1.00
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.
with fs1 = fs = 555.55
with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/d = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16771765
2 = Asl,com/(b*d)*(fs2/fc) = 0.35322354
v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)

```

```

---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.5098538
MRc (4.17) = 4.5595E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu

```

```

---->
Subcase: Rupture of tension steel

```

```

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

```

```

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

```

```

---->
Subcase rejected

```

```

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

```

```

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

```

```

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

```

```

---->
*cu (4.11) = 0.56860508
MRo (4.18) = 3.5813E+008
MRo < 0.8*MRc

```

```

---->
u = cu (unconfined full section) = 1.6866617E-005
Mu = MRc

```

```

-----
Calculation of ratio lb/d

```

```

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

```

```

-----
Calculation of Mu2-

```

```

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

```

```

u = 9.8367160E-006
Mu = 2.0582E+008

```

```

-----
with full section properties:

```

```

b = 200.00
d = 407.00
d' = 43.00
v = 1.27847
N = 1.5610E+006
fc = 15.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.0035
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.0035
we (5.4c) = 0.00
ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.00
The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization
of the rectangular sections confinement, which is expressed by (5.4d).
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)
"Theoretical Stress-Strain Model for Confined Concrete."

```


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

Aconf,max = 89600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

Aconf,min = 0.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

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

psh,min = Min(psh,x , psh,y) = 0.0019822

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) = 0.0019822

Lstir (Length of stirrups along Y) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.0019822

Lstir (Length of stirrups along X) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

s = 300.00

fywe = 555.55

fce = 15.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

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

lo/lou,min = lb/ld = 1.00

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

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

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

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

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

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

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

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

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

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

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

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

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

lo/lou,min = lb/ld = 1.00

```

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.79475296
2 = Asl,com/(b*d)*(fs2/fc) = 0.37736471
v = Asl,mid/(b*d)*(fsv/fc) = 0.7032706
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 9.8367160E-006
Mu = MRc
-----

```

Calculation of ratio lb/ld

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 165623.448$

Calculation of Shear Strength at edge 1, $V_{r1} = 165623.448$

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

$V_{\text{ColO}} = 165623.448$

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

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

$= 1$ (normal-weight concrete)

$f'_c = 15.00$, but $f_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.4825 \times 10^8$

$\nu_u = 2.2161626 \times 10^6$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.5610 \times 10^6$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$

where:

$V_{s1} = 55849.978$ is calculated for section web, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

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

$s/d = 0.83333333$

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

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

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

$s/d = 1.875$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 0.00$

From (11-11), ACI 440: $V_s + V_f \leq 185244.312$

$b_w = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 165623.448$

$V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} \cdot V_{\text{ColO}}$

$V_{\text{ColO}} = 165623.448$

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

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

$= 1$ (normal-weight concrete)

$f'_c = 15.00$, but $f_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.2485 \times 10^8$

$\nu_u = 2.2161626 \times 10^6$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.5610 \times 10^6$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$

where:

$V_{s1} = 55849.978$ is calculated for section web, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$
 V_{s1} is multiplied by $Col1 = 0.66666667$
 $s/d = 0.83333333$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 160.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 300.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.875$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
 From $(11-11)$, ACI 440: $V_s + V_f \leq 185244.312$
 $bw = 200.00$

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

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

Constant Properties

 Knowledge Factor, $\phi = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 15.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 18203.022$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$
 #####
 Max Height, $H_{max} = 450.00$
 Min Height, $H_{min} = 200.00$
 Max Width, $W_{max} = 450.00$
 Min Width, $W_{min} = 200.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.00
 Element Length, $L = 3000.00$
 Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{ou}, \min > 1$)
 No FRP Wrapping

Stepwise Properties

 At local axis: 2
 EDGE -A-
 Shear Force, $V_a = -5.2893364E-006$
 EDGE -B-
 Shear Force, $V_b = 5.2893364E-006$
 BOTH EDGES
 Axial Force, $F = -1.5610E+006$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{st} = 716.2831$

-Compression: $Asl_c = 3091.327$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $Asl_{ten} = 1746.726$
 -Compression: $Asl_{com} = 829.3805$
 -Middle: $Asl_{mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.8353$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 303967.895$
 with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 4.5595E+008$

$Mu_{1+} = 2.0582E+008$, 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

$Mu_{1-} = 4.5595E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 4.5595E+008$

$Mu_{2+} = 2.0582E+008$, 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

$Mu_{2-} = 4.5595E+008$, 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:

$\phi_u = 9.8367160E-006$

$M_u = 2.0582E+008$

with full section properties:

$b = 200.00$

$d = 407.00$

$d' = 43.00$

$v = 1.27847$

$N = 1.5610E+006$

$f_c = 15.00$

ϕ_o (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_o) = 0.0035$

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

From (5.4b), TBDY: $\phi_u = 0.0035$

ϕ_{ue} (5.4c) = 0.00

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.00$

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

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

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

$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.0019822$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$\phi_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

Lstir (Length of stirrups along X) = 1060.00
Astir (stirrups area) = 78.53982
Asec (section area) = 140000.00

s = 300.00

fywe = 555.55

fce = 15.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

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

lo/lou,min = lb/lb = 1.00

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

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

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

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

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

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

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

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

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

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

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

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

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

lo/lou,min = lb/lb = 1.00

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

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

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

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

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

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.79475296

2 = Asl,com/(b*d)*(fs2/fc) = 0.37736471

v = Asl,mid/(b*d)*(fsv/fc) = 0.7032706

and confined core properties:

b = 140.00

d = 377.00

d' = 13.00

fcc (5A.2, TBDY) = 15.00

cc (5A.5, TBDY) = 0.002

```

c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is not satisfied
--->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
--->
v* < v*sc - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
--->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
--->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008
MRo < 0.8*MRc
--->
u = cu (unconfined full section) = 9.8367160E-006
Mu = MRc
-----

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

Calculation of Mu1-
-----

-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.6866617E-005
Mu = 4.5595E+008
-----

with full section properties:
b = 450.00
d = 407.00
d' = 43.00

```

$v = 0.5682084$
 $N = 1.5610E+006$
 $f_c = 15.00$
 $\alpha (5A.5, TBDY) = 0.002$
 Final value of α : $\alpha = \text{shear_factor} * \text{Max}(\alpha_c, \alpha_s) = 0.0035$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\alpha_c = 0.0035$
 $\alpha_s (5.4c) = 0.00$
 $\alpha_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$
 The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
 $A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.
 $A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $\alpha_{sh,min} = \text{Min}(\alpha_{sh,x}, \alpha_{sh,y}) = 0.0019822$
 Expression ((5.4d), TBDY) for $\alpha_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\alpha_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$
 L_{stir} (Length of stirrups along Y) = 1060.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 140000.00

$\alpha_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$
 L_{stir} (Length of stirrups along X) = 1060.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 140000.00

$s = 300.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 15.00$
 From ((5.A.5), TBDY), TBDY: $\alpha_c = 0.002$
 α_c = confinement factor = 1.00
 $\gamma_1 = 0.00231479$
 $\gamma_{sh1} = 0.008$
 $f_{t1} = 666.66$
 $f_{y1} = 555.55$
 $\gamma_{su1} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $\gamma_{lo/\gamma_{ou,min}} = \gamma_{lb/\gamma_{ld}} = 1.00$
 $\gamma_{su1} = 0.4 * \gamma_{su1_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $\gamma_{su1_nominal} = 0.08$,
 For calculation of $\gamma_{su1_nominal}$ and $\gamma_1, \gamma_{sh1}, f_{t1}, f_{y1}$, it is considered characteristic value $f_{sy1} = f_{s1}/1.2$, from table 5.1, TBDY.
 $\gamma_1, \gamma_{sh1}, f_{t1}, f_{y1}$, are also multiplied by $\text{Min}(1, 1.25 * (\gamma_{lb}/\gamma_{ld})^{2/3})$, from 10.3.5, ASCE 41-17.
 with $f_{s1} = f_s = 555.55$
 with $E_{s1} = E_s = 200000.00$
 $\gamma_2 = 0.00231479$
 $\gamma_{sh2} = 0.008$
 $f_{t2} = 666.66$
 $f_{y2} = 555.55$
 $\gamma_{su2} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $\gamma_{lo/\gamma_{ou,min}} = \gamma_{lb/\gamma_{lb,min}} = 1.00$
 $\gamma_{su2} = 0.4 * \gamma_{su2_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $\gamma_{su2_nominal} = 0.08$,
 For calculation of $\gamma_{su2_nominal}$ and $\gamma_2, \gamma_{sh2}, f_{t2}, f_{y2}$, it is considered


```

characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.
 $y_1, sh_1, ft_1, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.
with  $f_{s2} = f_s = 555.55$ 
with  $E_{s2} = E_s = 200000.00$ 
 $y_v = 0.00231479$ 
 $sh_v = 0.008$ 
 $ft_v = 666.66$ 
 $f_{yv} = 555.55$ 
 $suv = 0.032$ 
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 1.00$ 
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$ 
From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,
considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY
For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, f_{yv}$ , it is considered
characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.
 $y_1, sh_1, ft_1, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.
with  $f_{sv} = f_s = 555.55$ 
with  $E_{sv} = E_s = 200000.00$ 
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.16771765$ 
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.35322354$ 
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.31256471$ 
and confined core properties:
 $b = 390.00$ 
 $d = 377.00$ 
 $d' = 13.00$ 
 $f_{cc} (5A.2, TBDY) = 15.00$ 
 $cc (5A.5, TBDY) = 0.002$ 
 $c = \text{confinement factor} = 1.00$ 
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.20891986$ 
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.4399979$ 
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.38935066$ 
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
 $v < v_{s,c}$  - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
 $v < s_{y1}$  - LHS eq.(4.7) is not satisfied
---->
 $v < v_{c,y1}$  - RHS eq.(4.6) is satisfied
---->
 $cu (4.10) = 0.5098538$ 
 $M_{Rc} (4.17) = 4.5595E+008$ 
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
-  $b, d, d'$  replaced by geometric parameters of the core:  $b_o, d_o, d'_o$ 
-  $N, 1, 2, v$  normalised to  $b_o \cdot d_o$ , instead of  $b \cdot d$ 
-  $f_{cc}, cc$ , used in lieu of  $f_c, c$ 
---->
Subcase: Rupture of tension steel
---->
 $v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied
---->
 $v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->

```

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

--->

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

--->

* c_u (4.11) = 0.56860508

M_{Ro} (4.18) = 3.5813E+008

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

--->

$u = c_u$ (unconfined full section) = 1.6866617E-005

$\mu_u = M_{Rc}$

Calculation of ratio I_b/I_d

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

Calculation of μ_{u2+}

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

$\phi_u = 9.8367160E-006$

$\mu_u = 2.0582E+008$

with full section properties:

$b = 200.00$

$d = 407.00$

$d' = 43.00$

$v = 1.27847$

$N = 1.5610E+006$

$f_c = 15.00$

ϕ_u (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0035$

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

From (5.4b), TBDY: $\phi_u = 0.0035$

ϕ_{ue} (5.4c) = 0.00

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

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

$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.0019822$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$\phi_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$s = 300.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A.5), TBDY), TBDY: $cc = 0.002$
 $c = \text{confinement factor} = 1.00$
 $y1 = 0.00231479$
 $sh1 = 0.008$
 $ft1 = 666.66$
 $fy1 = 555.55$
 $su1 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 1.00$
 $su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu1_nominal = 0.08$,
 For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
 characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs1 = fs = 555.55$
 with $Es1 = Es = 200000.00$
 $y2 = 0.00231479$
 $sh2 = 0.008$
 $ft2 = 666.66$
 $fy2 = 555.55$
 $su2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/lb, \min = 1.00$
 $su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs2 = fs = 555.55$
 with $Es2 = Es = 200000.00$
 $yv = 0.00231479$
 $shv = 0.008$
 $ftv = 666.66$
 $fyv = 555.55$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 1.00$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = fs = 555.55$
 with $Esv = Es = 200000.00$
 $1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.79475296$
 $2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.37736471$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.7032706$
 and confined core properties:
 $b = 140.00$
 $d = 377.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 15.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 1.22571$
 $2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.58199105$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 1.08462$
 Case/Assumption: Unconfined full section - Steel rupture
 ' does not satisfy Eq. (4.3)

--->

```

v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < s,y1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is not satisfied
--->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
--->
v* < v*s,c - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
--->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
--->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008
MRo < 0.8*MRc
--->
u = cu (unconfined full section) = 9.8367160E-006
Mu = MRc
-----

Calculation of ratio lb/d
-----
Adequate Lap Length: lb/d >= 1
-----
-----
-----
Calculation of Mu2-
-----
-----
-----
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.6866617E-005
Mu = 4.5595E+008
-----
with full section properties:
b = 450.00
d = 407.00
d' = 43.00
v = 0.5682084
N = 1.5610E+006
fc = 15.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.0035
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.0035

```

$$w_e (5.4c) = 0.00$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max}$ = 89600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min}$ = 0.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

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

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.0019822$$

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

$$p_{sh,x} ((5.4d), \text{TBDY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

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

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

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

$$p_{sh,y} ((5.4d), \text{TBDY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

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

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

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

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

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

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

For calculation of $esu_1_{nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

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

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

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

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

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

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

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

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

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

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

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

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

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

```

fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/ld = 1.00
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
    with fsv = fs = 555.55
    with Esv = Es = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.16771765
    2 = Asl,com/(b*d)*(fs2/fc) = 0.35322354
    v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
    2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
    v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
    cu (4.10) = 0.5098538
    MRc (4.17) = 4.5595E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
    - b, d, d' replaced by geometric parameters of the core: bo, do, d'o
    - N, 1, 2, v normalised to bo*do, instead of b*d
    - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
    *cu (4.11) = 0.56860508
    MRo (4.18) = 3.5813E+008
    MRo < 0.8*MRc

```

--->

$u = cu$ (unconfined full section) = 1.6866617E-005

$\mu = MRc$

Calculation of ratio l_b/l_d

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

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 165623.448$

Calculation of Shear Strength at edge 1, $V_{r1} = 165623.448$

$V_{r1} = V_{col}$ ((10.3), ASCE 41-17) = $k_n l V_{col0}$

$V_{col0} = 165623.448$

$k_n l = 1$ (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)

$f'_c = 15.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu = 1.4432E+008$

$V_u = 5.2893364E-006$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.5610E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$

where:

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

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

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

$s/d = 1.875$

$V_{s2} = 55849.978$ is calculated for section flange, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

V_{s2} is multiplied by $Col2 = 0.66666667$

$s/d = 0.83333333$

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

From (11-11), ACI 440: $V_s + V_f \leq 185244.312$

$b_w = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 165623.448$

$V_{r2} = V_{col}$ ((10.3), ASCE 41-17) = $k_n l V_{col0}$

$V_{col0} = 165623.448$

$k_n l = 1$ (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)

$f'_c = 15.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu = 1.2049E+008$

$V_u = 5.2893364E-006$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.5610E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$

where:

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

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

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

$s/d = 1.875$

$V_{s2} = 55849.978$ is calculated for section flange, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

V_{s2} is multiplied by $Col2 = 0.66666667$

$s/d = 0.83333333$

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

From (11-11), ACI 440: $V_s + V_f \leq 185244.312$

$b_w = 200.00$

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

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

At local axis: 2

Integration Section: (b)

Section Type: rclcs

Constant Properties

Knowledge Factor, $= 1.00$

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

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

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 15.00$

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

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 450.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 450.00$

Min Width, $W_{min} = 200.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/d \geq 1$)

No FRP Wrapping

Stepwise Properties

Bending Moment, $M = 1.2500E+008$

Shear Force, $V_2 = -114740.397$

Shear Force, $V_3 = -0.02811617$

Axial Force, $F = -1.5617E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 1030.442$

-Compression: $As_c = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $Asl_{ten} = 829.3805$

-Compression: $Asl_{com} = 1746.726$

-Middle: $Asl_{mid} = 1545.664$

Mean Diameter of Tension Reinforcement, $DbL = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = u = 0.02445758$

$u = y + p = 0.02445758$

- Calculation of y -

$y = (My * L_s / 3) / E_{eff} = 0.02445758$ ((4.29), Biskinis Phd))

$My = 3.4088E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 6000.00

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 2.7875E+013$

factor = 0.70

$A_g = 140000.00$

$fc' = 15.00$

$N = 1.5617E+006$

$E_c * I_g = 3.9822E+013$

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

Assuming neutral axis out of flange ($y > t/d$, compression zone NOT rectangular)

extended expressions (2.1)-(2.7) of Biskinis-Fardis (2009) are adopted with:

flange width, $b = 450.00$

web width, $b_w = 200.00$

flange thickness, $t = 200.00$

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

$y_{ten} = 1.0245677E-005$

with $f_y = 444.44$

$d = 407.00$

$y = 0.46709713$

$A = 0.1497109$

$B = 0.07985836$

with $pt = 0.0019822$

$pc = 0.00953713$

$pv = 0.00843933$

$N = 1.5617E+006$

$b = 450.00$

" = 0.10565111

$y_{comp} = 6.6398011E-006$

with $fc = 15.00$

$E_c = 18203.022$

$y = 0.54887164$

$A = 0.04186757$

$B = 0.03668953$

with $E_s = 200000.00$

CONFIRMATION: $y = 0.54887164 > t/d$

Calculation of ratio lb/d

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

- Calculation of p -

From table 10-8: $p = 0.00$

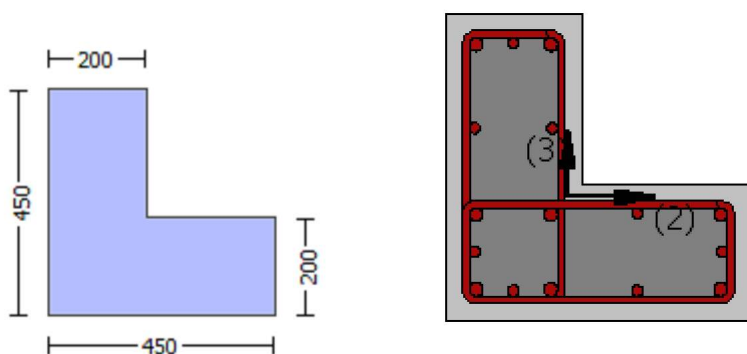
with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
shear control ratio $V_{yE}/V_{ColOE} = 1.8353$
 $d = 407.00$
 $s = 100.00$
 $t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.0019822$
 $A_v = 78.53982$, is the area of every stirrup
 $L_{stir} = 1060.00$, is the total Length of all stirrups parallel to loading (shear) direction
The term $2*t_f/b_w*(f_{fe}/f_s)$ is implemented to account for FRP contribution
where $f = 2*t_f/b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe}/f_s normalises f to steel strength
All these variables have already been given in Shear control ratio calculation.
 $NUD = 1.5617E+006$
 $Ag = 140000.00$
 $f_{cE} = 15.00$
 $f_{yE} = f_{yL} = 444.44$
 $pl = Area_{Tot_Long_Rein}/(b*d) = 0.02250488$
 $b = 450.00$
 $d = 407.00$
 $f_{cE} = 15.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1
At local axis: 2
Integration Section: (b)

Calculation No. 7

column C1, Floor 1
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)
Analysis: Uniform +X
Check: Shear capacity V_{Rd}
Edge: End
Local Axis: (3)



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

Integration Section: (b)

Section Type: rdcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 10.00$

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

Concrete Elasticity, $E_c = 18203.022$

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

Existing material: Concrete Strength, $f_c = f_{cm} = 15.00$

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

#####

Max Height, $H_{max} = 450.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 450.00$

Min Width, $W_{min} = 200.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

No FRP Wrapping

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -2.4005E+008$

Shear Force, $V_a = 0.02811617$

EDGE -B-

Bending Moment, $M_b = 1.2500E+008$

Shear Force, $V_b = -0.02811617$

BOTH EDGES

Axial Force, $F = -1.5617E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 1030.442$

-Compression: $A_{sl,c} = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 829.3805$

-Compression: $A_{sl,com} = 1746.726$

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

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41-17: Final Shear Capacity $V_R = \phi V_n = 148562.593$

V_n ((10-3), ASCE 41-17) = $k_n \phi V_{Col} = 148562.593$

$V_{Col} = 148562.593$

$k_n = 1.00$

$displacement_ductility_demand = 0.23359254$

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).

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

$f_c' = 10.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 1.2500E+008$
 $V_u = 0.02811617$
 $d = 0.8 \cdot h = 360.00$
 $N_u = 1.5617E+006$
 $A_g = 90000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 50265.482$
 where:
 $V_{s1} = 50265.482$ is calculated for section web, with:
 $d = 360.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 300.00$
 V_{s1} is multiplied by $Col1 = 0.66666667$
 $s/d = 0.83333333$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 160.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 300.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.875$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
 From (11-11), ACI 440: $V_s + V_f \leq 151251.347$
 $b_w = 200.00$

displacement ductility demand is calculated as δ_u / y

- Calculation of δ_u / y for END B -
 for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta_r = 0.00571311$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.02445758$ ((4.29), Biskinis Phd))
 $M_y = 3.4088E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 6000.00
 From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 2.7875E+013$
 $factor = 0.70$
 $A_g = 140000.00$
 $f_c' = 15.00$
 $N = 1.5617E+006$
 $E_c \cdot I_g = 3.9822E+013$

Calculation of Yielding Moment M_y

Calculation of δ_u and M_y according to Annex 7 -

Assuming neutral axis out of flange ($y > t/d$, compression zone NOT rectangular)
 extended expressions (2.1)-(2.7) of Biskinis-Fardis (2009) are adopted with:
 flange width, $b = 450.00$
 web width, $b_w = 200.00$
 flange thickness, $t = 200.00$

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 1.0245677E-005$
 with $f_y = 444.44$
 $d = 407.00$
 $y = 0.46709713$
 $A = 0.1497109$
 $B = 0.07985836$
 with $pt = 0.00452842$
 $pc = 0.00953713$
 $pv = 0.00843933$

$N = 1.5617E+006$
 $b = 450.00$
 $\mu = 0.10565111$
 $y_{comp} = 6.6398011E-006$
 with $f_c = 15.00$
 $E_c = 18203.022$
 $y = 0.54887164$
 $A = 0.04186757$
 $B = 0.03668953$
 with $E_s = 200000.00$
 CONFIRMATION: $y = 0.54887164 > t/d$

Calculation of ratio I_b/I_d

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

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

At local axis: 3

Integration Section: (b)

Calculation No. 8

column C1, Floor 1

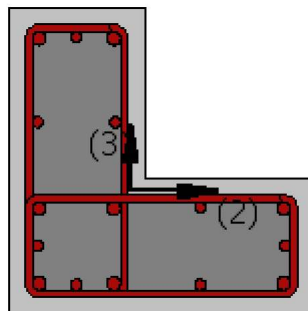
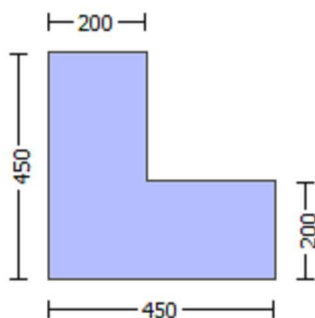
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity (μ)

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, $f_c = f_{cm} = 15.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 18203.022$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

Max Height, $H_{max} = 450.00$
Min Height, $H_{min} = 200.00$
Max Width, $W_{max} = 450.00$
Min Width, $W_{min} = 200.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.00
Element Length, $L = 3000.00$
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou,min} \geq 1$)
No FRP Wrapping

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

At local axis: 3
EDGE -A-
Shear Force, $V_a = 2.2161626E-006$
EDGE -B-
Shear Force, $V_b = -2.2161626E-006$
BOTH EDGES
Axial Force, $F = -1.5610E+006$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 716.2831$
-Compression: $A_{sl,c} = 3091.327$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 829.3805$
-Compression: $A_{sl,com} = 1746.726$
-Middle: $A_{sl,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.8353$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 303967.895$
with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 4.5595E+008$
 $\mu_{u1+} = 4.5595E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $\mu_{u1-} = 2.0582E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 4.5595E+008$
 $\mu_{u2+} = 4.5595E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the the static loading combination
 $\mu_{u2-} = 2.0582E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.6866617E-005$$

$$Mu = 4.5595E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.5682084$$

$$N = 1.5610E+006$$

$$f_c = 15.00$$

$$\phi_0 (5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0035$$

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

$$\text{From (5.4b), TB DY: } \phi_u = 0.0035$$

$$\phi_{ue} (5.4c) = 0.00$$

$$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

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

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.0019822$$

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

$$\phi_{sh,x} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

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

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

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

$$\phi_{sh,y} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

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

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

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

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

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

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

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

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

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

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

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

```

fy2 = 555.55
su2 = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/lb,min = 1.00
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
    with fs2 = fs = 555.55
    with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/ld = 1.00
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
    with fsv = fs = 555.55
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16771765
2 = Asl,com/(b*d)*(fs2/fc) = 0.35322354
v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
    2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
    v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.5098538
MRc (4.17) = 4.5595E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel

```



```

---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.56860508
MRo (4.18) = 3.5813E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 1.6866617E-005
Mu = MRc
-----

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 = 9.8367160E-006
Mu = 2.0582E+008
-----

with full section properties:
b = 200.00
d = 407.00
d' = 43.00
v = 1.27847
N = 1.5610E+006
fc = 15.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.0035
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.0035
we (5.4c) = 0.00
ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.00
The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization
of the rectangular sections confinement, which is expressed by (5.4d).
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)
"Theoretical Stress-Strain Model for Confined Concrete."
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
Aconf,max = 89600.00 is the confined core area at levels of member with hoops and
is calculated as the area of core enclosed by the center lines of the perimeter hoops.
Aconf,min = 0.00 is the confined core area at midway between the levels of hoops and
is calculated by reducing all the dimensions of the area Aconf,max by a length
equal to half the clear spacing between hoops.
AnoConf = 54733.333 is the unconfined core area which is equal to bi2/6 as defined at (A.2).
psh,min = Min(psh,x , psh,y) = 0.0019822
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) = 0.0019822
Lstir (Length of stirrups along Y) = 1060.00
Astir (stirrups area) = 78.53982
Asec (section area) = 140000.00

```

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.0019822$$

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

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

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

$$s = 300.00$$

$$fywe = 555.55$$

$$fce = 15.00$$

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

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

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

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

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

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

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

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

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

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

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

$$y2 = 0.00231479$$

$$sh2 = 0.008$$

$$ft2 = 666.66$$

$$fy2 = 555.55$$

$$su2 = 0.032$$

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

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

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

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

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

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

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

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

$$yv = 0.00231479$$

$$shv = 0.008$$

$$ftv = 666.66$$

$$fyv = 555.55$$

$$suv = 0.032$$

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

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

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

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

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

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

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

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

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.79475296$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.37736471$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.7032706$$

and confined core properties:

$$b = 140.00$$

$$d = 377.00$$

$$d' = 13.00$$

```

fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N1, N2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ec
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 9.8367160E-006
Mu = MRc
-----

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

Calculation of Mu2+
-----

-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.6866617E-005
Mu = 4.5595E+008
-----

with full section properties:
b = 450.00

```

$d = 407.00$
 $d' = 43.00$
 $v = 0.5682084$
 $N = 1.5610E+006$
 $f_c = 15.00$
 $\phi_c (5A.5, \text{TB DY}) = 0.002$
 Final value of ϕ_c : $\phi_c^* = \text{shear_factor} * \text{Max}(\phi_c, \phi_c) = 0.0035$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TB DY: $\phi_c = 0.0035$
 $\phi_w (5.4c) = 0.00$
 $\phi_{ase} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$
 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.
 $A_{\text{conf,max}} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{\text{conf,min}} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max}}$ by a length equal to half the clear spacing between hoops.
 $A_{\text{noConf}} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.0019822$
 Expression ((5.4d), TB DY) for $\phi_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\phi_{sh,x} ((5.4d), \text{TB DY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.0019822$
 L_{stir} (Length of stirrups along Y) = 1060.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 140000.00

$\phi_{sh,y} ((5.4d), \text{TB DY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.0019822$
 L_{stir} (Length of stirrups along X) = 1060.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 140000.00

$s = 300.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 15.00$
 From ((5.A5), TB DY), TB DY: $\phi_c = 0.002$
 ϕ_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
 $l_o/l_{o,min} = l_b/l_d = 1.00$
 $su_1 = 0.4 * esu1_{\text{nominal}} ((5.5), \text{TB DY}) = 0.032$
 From table 5A.1, TB DY: $esu1_{\text{nominal}} = 0.08$,
 For calculation of $esu1_{\text{nominal}}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TB DY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 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
 $l_o/l_{o,min} = l_b/l_{b,min} = 1.00$
 $su_2 = 0.4 * esu2_{\text{nominal}} ((5.5), \text{TB DY}) = 0.032$

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 $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
with $fs_2 = fs = 555.55$
with $Es_2 = Es = 200000.00$
 $y_v = 0.00231479$
 $sh_v = 0.008$
 $ft_v = 666.66$
 $fy_v = 555.55$
 $s_{uv} = 0.032$
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
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $s_{uv} = 0.4 \cdot es_{uv_nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,
considering characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY
For calculation of $es_{uv_nominal}$ and y_v , sh_v , ft_v , fy_v , it is considered
characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY.
 y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
with $fs_v = fs = 555.55$
with $Es_v = Es = 200000.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.16771765$
 $2 = A_{sl,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.35322354$
 $v = A_{sl,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.31256471$
and confined core properties:
 $b = 390.00$
 $d = 377.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 15.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.20891986$
 $2 = A_{sl,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.4399979$
 $v = A_{sl,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.38935066$
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
 $v < v_{s,c}$ - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
 $v < s_{y1}$ - LHS eq.(4.7) is not satisfied
--->
 $v < v_{c,y1}$ - RHS eq.(4.6) is satisfied
--->
 $cu (4.10) = 0.5098538$
 $M_{Rc} (4.17) = 4.5595E+008$
--->
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 not satisfied

--->

$*c_u(4.11) = 0.56860508$

$MR_o(4.18) = 3.5813E+008$

$MR_o < 0.8*MR_c$

--->

$u = c_u(\text{unconfined full section}) = 1.6866617E-005$

$\mu = MR_c$

Calculation of ratio l_b/l_d

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

Calculation of μ_2 -

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

$u = 9.8367160E-006$

$\mu = 2.0582E+008$

with full section properties:

$b = 200.00$

$d = 407.00$

$d' = 43.00$

$v = 1.27847$

$N = 1.5610E+006$

$f_c = 15.00$

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

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0035$

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

From (5.4b), TBDY: $c_u = 0.0035$

$w_e(5.4c) = 0.00$

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.00$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

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

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.0019822$

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)

$p_{sh,x}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$p_{sh,y}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$s = 300.00$

```

fywe = 555.55
fce = 15.00
From ((5A.5), TBDY), TBDY: cc = 0.002
c = confinement factor = 1.00
y1 = 0.00231479
sh1 = 0.008
ft1 = 666.66
fy1 = 555.55
su1 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/d = 1.00
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.
with fs1 = fs = 555.55
with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.
with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/d = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.79475296
2 = Asl,com/(b*d)*(fs2/fc) = 0.37736471
v = Asl,mid/(b*d)*(fsv/fc) = 0.7032706
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
Case/Assumption: Unconfinedsd full section - Steel rupture

```

' does not satisfy Eq. (4.3)
 --->
 $v < v_{s,c}$ - RHS eq.(4.5) is not satisfied
 --->
 Case/Assumption Rejected.
 --->
 New Case/Assumption: Unconfined full section - Spalling of concrete cover
 ' satisfies Eq. (4.4)
 --->
 $v < s_{y1}$ - LHS eq.(4.7) is not satisfied
 --->
 $v < v_{c,y1}$ - RHS eq.(4.6) is not satisfied
 --->
 c_u (4.11) = 0.87422556
 M_{Rc} (4.18) = 2.0582E+008
 --->
 New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
 In expressions below, the following modifications have been made
 - b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o
 - N_1, N_2, v normalised to $b_o \cdot d_o$, instead of $b \cdot d$
 - f_{cc}, ϵ_{cc} parameters of confined concrete, f_{cc}, ϵ_{cc} used in lieu of f_c, ϵ_{cu}
 --->
 Subcase: Rupture of tension steel
 --->
 $v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied
 --->
 $v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied
 --->
 Subcase rejected
 --->
 New Subcase: Failure of compression zone
 --->
 $v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied
 --->
 $v^* < v^*_{c,y1}$ - RHS eq.(4.6) is not satisfied
 --->
 $*c_u$ (4.11) = 1.00
 M_{Ro} (4.18) = 1.2754E+008
 $M_{Ro} < 0.8 \cdot M_{Rc}$
 --->
 $u = c_u$ (unconfined full section) = 9.8367160E-006
 $\mu_u = M_{Rc}$

 Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 165623.448$

Calculation of Shear Strength at edge 1, $V_{r1} = 165623.448$

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

$V_{ColO} = 165623.448$

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

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

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

$f'_c = 15.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.4825E+008$

$V_u = 2.2161626E-006$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.5610E+006$
 $A_g = 90000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$
 where:
 $V_{s1} = 55849.978$ is calculated for section web, with:
 $d = 360.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 300.00$
 V_{s1} is multiplied by $Col1 = 0.66666667$
 $s/d = 0.83333333$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 160.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 300.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.875$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
 From (11-11), ACI 440: $V_s + V_f \leq 185244.312$
 $bw = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 165623.448$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 165623.448$
 $knl = 1$ (zero step-static loading)

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

$= 1$ (normal-weight concrete)
 $f'_c = 15.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 1.2485E+008$
 $V_u = 2.2161626E+006$
 $d = 0.8*h = 360.00$
 $N_u = 1.5610E+006$
 $A_g = 90000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$
 where:
 $V_{s1} = 55849.978$ is calculated for section web, with:
 $d = 360.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 300.00$
 V_{s1} is multiplied by $Col1 = 0.66666667$
 $s/d = 0.83333333$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 160.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 300.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.875$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
 From (11-11), ACI 440: $V_s + V_f \leq 185244.312$
 $bw = 200.00$

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

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

At Shear local axis: 2
(Bending local axis: 3)
Section Type: 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, $f_c = f_{cm} = 15.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 18203.022$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

Max Height, $H_{max} = 450.00$
Min Height, $H_{min} = 200.00$
Max Width, $W_{max} = 450.00$
Min Width, $W_{min} = 200.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.00
Element Length, $L = 3000.00$
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou}, \min \geq 1$)
No FRP Wrapping

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = -5.2893364E-006$
EDGE -B-
Shear Force, $V_b = 5.2893364E-006$
BOTH EDGES
Axial Force, $F = -1.5610E+006$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 716.2831$
-Compression: $A_{sl,c} = 3091.327$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 1746.726$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.8353$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 303967.895$
with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 4.5595E+008$
 $\mu_{u1+} = 2.0582E+008$, 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
 $\mu_{u1-} = 4.5595E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 4.5595E+008$
 $\mu_{u2+} = 2.0582E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the static loading combination
 $\mu_{u2-} = 4.5595E+008$, 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:

$$\mu = 9.8367160E-006$$

$$\mu_{1+} = 2.0582E+008$$

with full section properties:

$$b = 200.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$\nu = 1.27847$$

$$N = 1.5610E+006$$

$$f_c = 15.00$$

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

$$\text{Final value of } \mu_{1+}: \mu_{1+}^* = \text{shear_factor} * \text{Max}(\mu_{1+}, \alpha) = 0.0035$$

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

$$\text{From (5.4b), TB DY: } \mu_{1+} = 0.0035$$

$$\mu_{1+} (5.4c) = 0.00$$

$$\mu_{1+} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$$

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.

$A_{\text{conf,max}} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max}}$ by a length equal to half the clear spacing between hoops.

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

$$\mu_{1+, \text{min}} = \text{Min}(\mu_{1+, x}, \mu_{1+, y}) = 0.0019822$$

Expression ((5.4d), TB DY) for $\mu_{1+, \text{min}}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\mu_{1+, x} ((5.4d), \text{TB DY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.0019822$$

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

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

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

$$\mu_{1+, y} ((5.4d), \text{TB DY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.0019822$$

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

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

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

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

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

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

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

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs1 = fs = 555.55$
 with $Es1 = Es = 200000.00$
 $y2 = 0.00231479$
 $sh2 = 0.008$
 $ft2 = 666.66$
 $fy2 = 555.55$
 $su2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, min = lb/lb, min = 1.00$
 $su2 = 0.4 \cdot esu2_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs2 = fs = 555.55$
 with $Es2 = Es = 200000.00$
 $yv = 0.00231479$
 $shv = 0.008$
 $ftv = 666.66$
 $fyv = 555.55$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, min = lb/ld = 1.00$
 $suv = 0.4 \cdot esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = fs = 555.55$
 with $Esv = Es = 200000.00$
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.79475296$
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.37736471$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.7032706$

and confined core properties:

$b = 140.00$
 $d = 377.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 15.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 1.22571$
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.58199105$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 1.08462$

Case/Assumption: Unconfined full section - Steel rupture

' does not satisfy Eq. (4.3)

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

Case/Assumption Rejected.

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

' satisfies Eq. (4.4)

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

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

$cu (4.11) = 0.87422556$

$MRC (4.18) = 2.0582E+008$

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, ν_1 , ν_2 , ν normalised to $\nu_0 \cdot d_o$, instead of $b \cdot d$
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu

Subcase: Rupture of tension steel

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

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

Subcase rejected

New Subcase: Failure of compression zone

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

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

ν^*_{cu} (4.11) = 1.00

M_{Ro} (4.18) = 1.2754E+008

M_{Ro} < 0.8*M_{Rc}

$\nu_u = \nu_{cu}$ (unconfined full section) = 9.8367160E-006

M_u = M_{Rc}

Calculation of ratio lb/l_d

Adequate Lap Length: lb/l_d >= 1

Calculation of Mu1-

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

$\nu_u = 1.6866617E-005$

M_u = 4.5595E+008

with full section properties:

b = 450.00

d = 407.00

d' = 43.00

$\nu = 0.5682084$

N = 1.5610E+006

fc = 15.00

co (5A.5, TBDY) = 0.002

Final value of ν_{cu} : $\nu_{cu}^* = \text{shear_factor} \cdot \text{Max}(\nu_{cu}, \nu_{cc}) = 0.0035$

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

From (5.4b), TBDY: $\nu_{cu} = 0.0035$

ν_{we} (5.4c) = 0.00

$\nu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.00$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

A_{conf,max} = 89600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

A_{conf,min} = 0.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area A_{conf,max} by a length equal to half the clear spacing between hoops.

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

$\nu_{psh,min} = \text{Min}(\nu_{psh,x}, \nu_{psh,y}) = 0.0019822$

Expression ((5.4d), TBDY) for $\nu_{psh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without

earthquake detailing (90° closed stirrups)

$$psh,x \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.0019822$$

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

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

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

$$psh,y \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.0019822$$

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

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

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

$$s = 300.00$$

$$fywe = 555.55$$

$$fce = 15.00$$

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

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

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

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, ASCE 41-17.

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

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

$$y2 = 0.00231479$$

$$sh2 = 0.008$$

$$ft2 = 666.66$$

$$fy2 = 555.55$$

$$su2 = 0.032$$

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

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

$$su2 = 0.4 * esu2_nominal \text{ ((5.5), TBDY)} = 0.032$$

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

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

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

$$yv = 0.00231479$$

$$shv = 0.008$$

$$ftv = 666.66$$

$$fyv = 555.55$$

$$suv = 0.032$$

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

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

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

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 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, ASCE 41-17.

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

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.16771765$$

```

2 = Asl,com/(b*d)*(fs2/fc) = 0.35322354
v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.5098538
MRc (4.17) = 4.5595E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N1, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
--->
v* < v*sc - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
--->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
--->
*cu (4.11) = 0.56860508
MRo (4.18) = 3.5813E+008
MRo < 0.8*MRc
--->
u = cu (unconfined full section) = 1.6866617E-005
Mu = MRc

```

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Mu2+

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

$$\phi_u = 9.8367160E-006$$

$$\mu_u = 2.0582E+008$$

with full section properties:

$$b = 200.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$\nu = 1.27847$$

$$N = 1.5610E+006$$

$$f_c = 15.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0035$$

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

$$\text{From (5.4b), TB DY: } \phi_u = 0.0035$$

$$\omega_e (5.4c) = 0.00$$

$$\text{ase} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$$

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)

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

$A_{\text{conf,max}} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max}}$ by a length equal to half the clear spacing between hoops.

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

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.0019822$$

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

$$\phi_{sh,x} ((5.4d), \text{TB DY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.0019822$$

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

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

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

$$\phi_{sh,y} ((5.4d), \text{TB DY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.0019822$$

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

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

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

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

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

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

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

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

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

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

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$


```

su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.79475296
2 = Asl,com/(b*d)*(fs2/fc) = 0.37736471
v = Asl,mid/(b*d)*(fsv/fc) = 0.7032706
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N1, N2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->

```

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

--->

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

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

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

--->

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

--->

*cu (4.11) = 1.00

MRO (4.18) = 1.2754E+008

MRO < 0.8*MRc

--->

u = cu (unconfined full section) = 9.8367160E-006

Mu = MRc

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Mu2-

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

u = 1.6866617E-005

Mu = 4.5595E+008

with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.5682084

N = 1.5610E+006

fc = 15.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.0035

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

From (5.4b), TBDY: cu = 0.0035

we (5.4c) = 0.00

ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.00

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

Aconf,max = 89600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

Aconf,min = 0.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 54733.333 is the unconfined core area which is equal to bi2/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.0019822

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) = 0.0019822

Lstir (Length of stirrups along Y) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

$$\text{psh,y ((5.4d), TBDY)} = \text{Lstir} \cdot \text{Astir} / (\text{Asec} \cdot \text{s}) = 0.0019822$$

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

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

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

$$\text{s} = 300.00$$

$$\text{fywe} = 555.55$$

$$\text{fce} = 15.00$$

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

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

$$\text{y1} = 0.00231479$$

$$\text{sh1} = 0.008$$

$$\text{ft1} = 666.66$$

$$\text{fy1} = 555.55$$

$$\text{su1} = 0.032$$

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

$$\text{lo/lou,min} = \text{lb/lb} = 1.00$$

$$\text{su1} = 0.4 \cdot \text{esu1_nominal} ((5.5), \text{TBDY}) = 0.032$$

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 $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$, from 10.3.5, ASCE 41-17.

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

$$\text{with Es1} = \text{Es} = 200000.00$$

$$\text{y2} = 0.00231479$$

$$\text{sh2} = 0.008$$

$$\text{ft2} = 666.66$$

$$\text{fy2} = 555.55$$

$$\text{su2} = 0.032$$

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

$$\text{lo/lou,min} = \text{lb}/\text{lb,min} = 1.00$$

$$\text{su2} = 0.4 \cdot \text{esu2_nominal} ((5.5), \text{TBDY}) = 0.032$$

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 $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with fs2} = \text{fs} = 555.55$$

$$\text{with Es2} = \text{Es} = 200000.00$$

$$\text{yv} = 0.00231479$$

$$\text{shv} = 0.008$$

$$\text{ftv} = 666.66$$

$$\text{fyv} = 555.55$$

$$\text{suv} = 0.032$$

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

$$\text{lo/lou,min} = \text{lb}/\text{ld} = 1.00$$

$$\text{suv} = 0.4 \cdot \text{esuv_nominal} ((5.5), \text{TBDY}) = 0.032$$

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 $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with fsv} = \text{fs} = 555.55$$

$$\text{with Esv} = \text{Es} = 200000.00$$

$$1 = \text{Asl,ten}/(\text{b} \cdot \text{d}) \cdot (\text{fs1}/\text{fc}) = 0.16771765$$

$$2 = \text{Asl,com}/(\text{b} \cdot \text{d}) \cdot (\text{fs2}/\text{fc}) = 0.35322354$$

$$\text{v} = \text{Asl,mid}/(\text{b} \cdot \text{d}) \cdot (\text{fsv}/\text{fc}) = 0.31256471$$

and confined core properties:

$$\text{b} = 390.00$$

$$\text{d} = 377.00$$

$$\text{d}' = 13.00$$

$$\text{fcc (5A.2, TBDY)} = 15.00$$

```

cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.5098538
MRc (4.17) = 4.5595E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ec
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.56860508
MRo (4.18) = 3.5813E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 1.6866617E-005
Mu = MRc
-----

Calculation of ratio lb/ld
-----
Adequate Lap Length: lb/ld >= 1
-----
-----
-----
-----
Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 165623.448
-----
Calculation of Shear Strength at edge 1, Vr1 = 165623.448
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VColO
VColO = 165623.448
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)
 $f'_c = 15.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 1.4432E+008$
 $V_u = 5.2893364E-006$
 $d = 0.8 \cdot h = 360.00$
 $N_u = 1.5610E+006$
 $A_g = 90000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$
 where:
 $V_{s1} = 0.00$ is calculated for section web, with:
 $d = 160.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 300.00$
 V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 1.875$
 $V_{s2} = 55849.978$ is calculated for section flange, with:
 $d = 360.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 300.00$
 V_{s2} is multiplied by $Col2 = 0.66666667$
 $s/d = 0.83333333$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
 From (11-11), ACI 440: $V_s + V_f \leq 185244.312$
 $b_w = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 165623.448$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 165623.448$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f \cdot V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 $f'_c = 15.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 1.2049E+008$
 $V_u = 5.2893364E-006$
 $d = 0.8 \cdot h = 360.00$
 $N_u = 1.5610E+006$
 $A_g = 90000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$
 where:
 $V_{s1} = 0.00$ is calculated for section web, with:
 $d = 160.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 300.00$
 V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 1.875$
 $V_{s2} = 55849.978$ is calculated for section flange, with:
 $d = 360.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 300.00$
 V_{s2} is multiplied by $Col2 = 0.66666667$
 $s/d = 0.83333333$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
 From (11-11), ACI 440: $V_s + V_f \leq 185244.312$
 $b_w = 200.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (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, ASCE 41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 15.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 450.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 450.00$

Min Width, $W_{min} = 200.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/d \geq 1$)

No FRP Wrapping

Stepwise Properties

Bending Moment, $M = 1.4356E+008$

Shear Force, $V_2 = -114740.397$

Shear Force, $V_3 = -0.02811617$

Axial Force, $F = -1.5617E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 1030.442$

-Compression: $As_c = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1746.726$

-Compression: $As_{c,com} = 829.3805$

-Middle: $As_{l,mid} = 1545.664$

Mean Diameter of Tension Reinforcement, $Db_L = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $\phi_{R,u} = \phi_y + \phi_p = 0.00220784$

$\phi_u = \phi_y + \phi_p = 0.00220784$

- Calculation of ϕ_y -

$\phi_y = (M_y * L_s / 3) / E_{eff} = 0.00220784$ ((4.29), Biskinis Phd))

$M_y = 1.4757E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1251.181

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 2.7875E+013$

factor = 0.70

$A_g = 140000.00$

$f_c' = 15.00$

$N = 1.5617E+006$

$$E_c \cdot I_g = 3.9822E+013$$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 1.4507672E-005$
 with $f_y = 444.44$
 $d = 407.00$
 $y = 0.62365079$
 $A = 0.09380482$
 $B = 0.07620117$
 with $p_t = 0.0019822$
 $p_c = 0.01018895$
 $p_v = 0.0189885$
 $N = 1.5617E+006$
 $b = 200.00$
 $" = 0.10565111$
 $y_{\text{comp}} = 3.5726923E-006$
 with $f_c = 15.00$
 $E_c = 18203.022$
 $y = 1.02007$
 $A = -0.01403851$
 $B = 0.03303234$
 with $E_s = 200000.00$

Calculation of ratio I_b/I_d

Adequate Lap Length: $I_b/I_d \geq 1$

- Calculation of p -

From table 10-8: $p = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $I_b/I_d \geq 1$
 shear control ratio $V_y E / V_{col} E = 1.8353$
 $d = 407.00$
 $s = 100.00$
 $t = A_v / (b_w \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = A_v \cdot L_{stir} / (A_g \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.0019822$
 $A_v = 78.53982$, is the area of every stirrup
 $L_{stir} = 1060.00$, is the total Length of all stirrups parallel to loading (shear) direction
 The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ is implemented to account for FRP contribution
 where $f = 2 \cdot t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength
 All these variables have already been given in Shear control ratio calculation.
 $NUD = 1.5617E+006$
 $A_g = 140000.00$
 $f_{cE} = 15.00$
 $f_{yE} = f_{yIE} = 444.44$
 $p_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.05063599$
 $b = 200.00$
 $d = 407.00$
 $f_{cE} = 15.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

Calculation No. 9

column C1, Floor 1

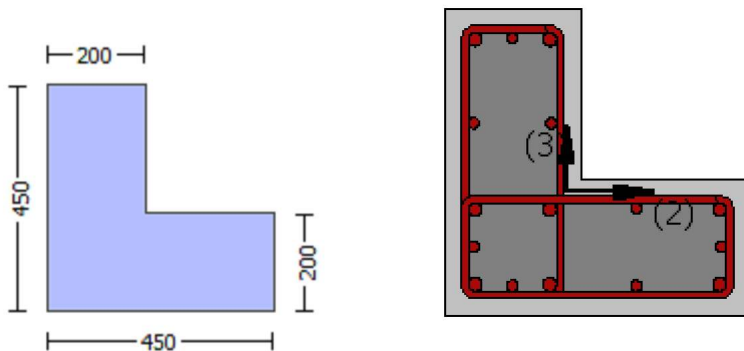
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rdcS

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 10.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 18203.022$

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, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 15.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

Max Height, $H_{max} = 450.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 450.00$

Min Width, $W_{min} = 200.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{o,min} = l_b/l_d \geq 1$)
No FRP Wrapping

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = 2.4684E+007$
Shear Force, $V_a = 203511.132$
EDGE -B-
Bending Moment, $M_b = 1.6143E+008$
Shear Force, $V_b = -203511.132$
BOTH EDGES
Axial Force, $F = -1.5625E+006$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 1545.664$
-Compression: $A_{sl,c} = 2576.106$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 1746.726$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 1545.664$
Mean Diameter of Tension Reinforcement, $D_{bL,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = V_n = 172832.648$
 V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{Co10} = 172832.648$
 $V_{Co1} = 246903.783$
 $k_n = 0.70$
 $displacement_ductility_demand = 171.3653$

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)
 $f'_c = 10.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 2.4684E+007$
 $V_u = 203511.132$
 $d = 0.8 \cdot h = 360.00$
 $N_u = 1.5625E+006$
 $A_g = 90000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 50265.482$
where:
 $V_{s1} = 0.00$ is calculated for section web, with:
 $d = 160.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 300.00$
 V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 1.875$
 $V_{s2} = 50265.482$ is calculated for section flange, with:
 $d = 360.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 300.00$
 V_{s2} is multiplied by $Col2 = 0.66666667$
 $s/d = 0.83333333$
 V_f ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: $V_s + V_f \leq 151251.347$
 $b_w = 200.00$

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 $\theta = 0.0906786$
 $y = (M_y * L_s / 3) / E_{eff} = 0.00052915$ ((4.29), Biskinis Phd))
 $M_y = 1.4750E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 2.7875E+013$
factor = 0.70
Ag = 140000.00
fc' = 15.00
N = 1.5625E+006
 $E_c * I_g = 3.9822E+013$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 1.4509707E-005$
with $f_y = 444.44$
d = 407.00
 $y = 0.62370357$
A = 0.09382593
B = 0.07622229
with $p_t = 0.02145854$
pc = 0.01018895
pv = 0.0189885
N = 1.5625E+006
b = 200.00
" = 0.10565111
 $y_{comp} = 3.5712582E-006$
with $f_c = 15.00$
Ec = 18203.022
 $y = 1.02048$
A = -0.01407015
B = 0.03303234
with $E_s = 200000.00$

Calculation of ratio I_b/I_d

Adequate Lap Length: $I_b/I_d \geq 1$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1
At local axis: 2
Integration Section: (a)

Calculation No. 10

column C1, Floor 1

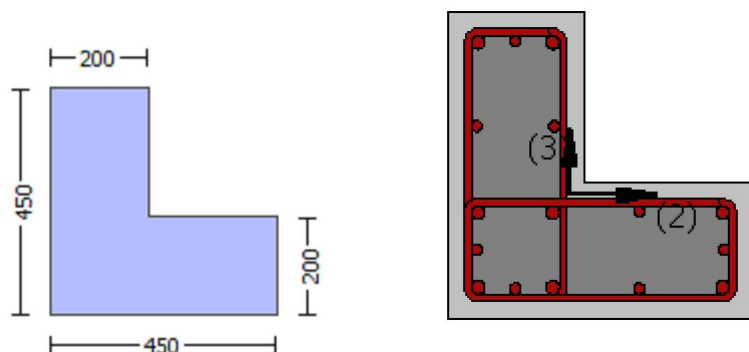
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ)

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, $f_c = f_{cm} = 15.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height, $H_{max} = 450.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 450.00$

Min Width, $W_{min} = 200.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou,min} \geq 1$)

No FRP Wrapping

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 2.2161626E-006$

EDGE -B-

Shear Force, $V_b = -2.2161626E-006$

BOTH EDGES

Axial Force, $F = -1.5610E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 716.2831$

-Compression: $As_c = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 829.3805$

-Compression: $As_{c,com} = 1746.726$

-Middle: $As_{l,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.8353$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 303967.895$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 4.5595E+008$

$Mu_{1+} = 4.5595E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.0582E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 4.5595E+008$

$Mu_{2+} = 4.5595E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.0582E+008$, 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:

$\phi_u = 1.6866617E-005$

$M_u = 4.5595E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.5682084$

$N = 1.5610E+006$

$f_c = 15.00$

$\phi_c(5A.5, TBDY) = 0.002$

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0035$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.0035$

$\phi_{we}(5.4c) = 0.00$

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.00$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$\phi_{psh,min} = \text{Min}(\phi_{psh,x}, \phi_{psh,y}) = 0.0019822$

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)

$$\text{psh}_x ((5.4d), \text{TBDY}) = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.0019822$$

$$\text{Lstir (Length of stirrups along Y)} = 1060.00$$

$$\text{Astir (stirrups area)} = 78.53982$$

$$\text{Asec (section area)} = 140000.00$$

$$\text{psh}_y ((5.4d), \text{TBDY}) = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.0019822$$

$$\text{Lstir (Length of stirrups along X)} = 1060.00$$

$$\text{Astir (stirrups area)} = 78.53982$$

$$\text{Asec (section area)} = 140000.00$$

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From } ((5.A5), \text{TBDY}), \text{TBDY: } cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/ld = 1.00$$

$$su_1 = 0.4 * esu_1_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_1_{\text{nominal}} = 0.08,$$

For calculation of esu_1_{nominal} and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

$$y_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs_1 = fs = 555.55$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/lb, \min = 1.00$$

$$su_2 = 0.4 * esu_2_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_2_{\text{nominal}} = 0.08,$$

For calculation of esu_2_{nominal} and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

$$y_2, sh_2, ft_2, fy_2, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs_2 = fs = 555.55$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

$$fy_v = 555.55$$

$$su_v = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/ld = 1.00$$

$$su_v = 0.4 * esuv_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } esuv_{\text{nominal}} = 0.08,$$

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_{\text{nominal}}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$$y_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fsv = fs = 555.55$$

$$\text{with } Es_v = Es = 200000.00$$

$$1 = \text{Asl,ten} / (b * d) * (fs_1 / f_c) = 0.16771765$$

$$2 = \text{Asl,com} / (b * d) * (fs_2 / f_c) = 0.35322354$$

```

v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < s,y1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.5098538
MRc (4.17) = 4.5595E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
--->
v* < v*s,c - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
--->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
--->
*cu (4.11) = 0.56860508
MRo (4.18) = 3.5813E+008
MRo < 0.8*MRc
--->
u = cu (unconfined full section) = 1.6866617E-005
Mu = MRc

```

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 = 9.8367160E-006
Mu = 2.0582E+008

with full section properties:

b = 200.00
d = 407.00
d' = 43.00
v = 1.27847
N = 1.5610E+006

fc = 15.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.0035

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.0035

we (5.4c) = 0.00

ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.00

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max = 89600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

Aconf,min = 0.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 54733.333 is the unconfined core area which is equal to bi2/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.0019822

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) = 0.0019822

Lstir (Length of stirrups along Y) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.0019822

Lstir (Length of stirrups along X) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

s = 300.00

fywe = 555.55

fce = 15.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

```

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/d = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.79475296
2 = Asl,com/(b*d)*(fs2/fc) = 0.37736471
v = Asl,mid/(b*d)*(fsv/fc) = 0.7032706
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < s,y1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is not satisfied
--->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied

```



```

---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 9.8367160E-006
Mu = MRc
-----

Calculation of ratio lb/ld
-----
Adequate Lap Length: lb/ld >= 1
-----
-----
Calculation of Mu2+
-----
-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.6866617E-005
Mu = 4.5595E+008
-----

with full section properties:
b = 450.00
d = 407.00
d' = 43.00
v = 0.5682084
N = 1.5610E+006
fc = 15.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.0035
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.0035
we (5.4c) = 0.00
ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.00
The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization
of the rectangular sections confinement, which is expressed by (5.4d).
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)
"Theoretical Stress-Strain Model for Confined Concrete."
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
Aconf,max = 89600.00 is the confined core area at levels of member with hoops and
is calculated as the area of core enclosed by the center lines of the perimeter hoops.
Aconf,min = 0.00 is the confined core area at midway between the levels of hoops and
is calculated by reducing all the dimensions of the area Aconf,max by a length
equal to half the clear spacing between hoops.
AnoConf = 54733.333 is the unconfined core area which is equal to bi2/6 as defined at (A.2).
psh,min = Min(psh,x , psh,y) = 0.0019822
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) = 0.0019822
Lstir (Length of stirrups along Y) = 1060.00
Astir (stirrups area) = 78.53982
Asec (section area) = 140000.00
-----
psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.0019822

```

Lstir (Length of stirrups along X) = 1060.00
Astir (stirrups area) = 78.53982
Asec (section area) = 140000.00

s = 300.00

fywe = 555.55

fce = 15.00

From ((5.A.5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16771765

2 = Asl,com/(b*d)*(fs2/fc) = 0.35322354

v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471

and confined core properties:

b = 390.00

d = 377.00

d' = 13.00

fcc (5A.2, TBDY) = 15.00

cc (5A.5, TBDY) = 0.002

```

c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.5098538
MRc (4.17) = 4.5595E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
--->
v* < v*sc - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
--->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
--->
*cu (4.11) = 0.56860508
MRo (4.18) = 3.5813E+008
MRo < 0.8*MRc
--->
u = cu (unconfined full section) = 1.6866617E-005
Mu = MRc
-----

Calculation of ratio lb/d
-----
Adequate Lap Length: lb/d >= 1
-----
-----

Calculation of Mu2-
-----
-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 9.8367160E-006
Mu = 2.0582E+008
-----

with full section properties:
b = 200.00
d = 407.00
d' = 43.00

```

$v = 1.27847$
 $N = 1.5610E+006$
 $f_c = 15.00$
 $\alpha (5A.5, TBDY) = 0.002$
 Final value of α : $\alpha = \text{shear_factor} * \text{Max}(\alpha_c, \alpha_s) = 0.0035$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\alpha_c = 0.0035$
 $\alpha_s (5.4c) = 0.00$
 $\alpha_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$
 The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
 $A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.
 $A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $\alpha_{sh,min} = \text{Min}(\alpha_{sh,x}, \alpha_{sh,y}) = 0.0019822$
 Expression ((5.4d), TBDY) for $\alpha_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\alpha_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$
 L_{stir} (Length of stirrups along Y) = 1060.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 140000.00

$\alpha_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$
 L_{stir} (Length of stirrups along X) = 1060.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 140000.00

$s = 300.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 15.00$
 From ((5.A5), TBDY), TBDY: $\alpha_c = 0.002$
 α_c = confinement factor = 1.00
 $y_1 = 0.00231479$
 $sh_1 = 0.008$
 $ft_1 = 666.66$
 $fy_1 = 555.55$
 $su_1 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $su_1 = 0.4 * \alpha_{su1,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $\alpha_{su1,nominal} = 0.08$,
 For calculation of $\alpha_{su1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = f_s/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_1 = f_s = 555.55$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.00231479$
 $sh_2 = 0.008$
 $ft_2 = 666.66$
 $fy_2 = 555.55$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$
 $su_2 = 0.4 * \alpha_{su2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $\alpha_{su2,nominal} = 0.08$,
 For calculation of $\alpha_{su2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered

```

characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.
with  $f_{s2} = f_s = 555.55$ 
with  $E_{s2} = E_s = 200000.00$ 
 $y_v = 0.00231479$ 
 $sh_v = 0.008$ 
 $ft_v = 666.66$ 
 $fy_v = 555.55$ 
 $suv = 0.032$ 
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 1.00$ 
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$ 
From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,
considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY
For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered
characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.
with  $f_{sv} = f_s = 555.55$ 
with  $E_{sv} = E_s = 200000.00$ 
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.79475296$ 
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.37736471$ 
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.7032706$ 
and confined core properties:
 $b = 140.00$ 
 $d = 377.00$ 
 $d' = 13.00$ 
 $f_{cc} (5A.2, TBDY) = 15.00$ 
 $cc (5A.5, TBDY) = 0.002$ 
 $c = \text{confinement factor} = 1.00$ 
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 1.22571$ 
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.58199105$ 
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 1.08462$ 
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
 $v < v_{s,c}$  - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
 $v < s_{y1}$  - LHS eq.(4.7) is not satisfied
---->
 $v < v_{c,y1}$  - RHS eq.(4.6) is not satisfied
---->
 $cu (4.11) = 0.87422556$ 
 $M_{Rc} (4.18) = 2.0582E+008$ 
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
-  $b, d, d'$  replaced by geometric parameters of the core:  $b_o, d_o, d'_o$ 
-  $N, 1, 2, v$  normalised to  $b_o \cdot d_o$ , instead of  $b \cdot d$ 
-  $f_{cc}, cc$ , used in lieu of  $f_c, c$ 
---->
Subcase: Rupture of tension steel
---->
 $v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied
---->
 $v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->

```

$v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

--->

$v^* < v^*_{c,y1}$ - RHS eq.(4.6) is not satisfied

--->

$*c_u (4.11) = 1.00$

$M_{Ro} (4.18) = 1.2754E+008$

$M_{Ro} < 0.8*M_{Rc}$

--->

$u = c_u$ (unconfined full section) = $9.8367160E-006$

$\mu = M_{Rc}$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 165623.448$

Calculation of Shear Strength at edge 1, $V_{r1} = 165623.448$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{ColO}$

$V_{ColO} = 165623.448$

$k_{nl} = 1$ (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)

$f'_c = 15.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.4825E+008$

$\mu_v = 2.2161626E-006$

$d = 0.8*h = 360.00$

$N_u = 1.5610E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$

where:

$V_{s1} = 55849.978$ is calculated for section web, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

V_{s1} is multiplied by $Col1 = 0.66666667$

$s/d = 0.83333333$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.875$

$V_f ((11-3)-(11.4), ACI 440) = 0.00$

From (11-11), ACI 440: $V_s + V_f \leq 185244.312$

$b_w = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 165623.448$

$V_{r2} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{ColO}$

$V_{ColO} = 165623.448$

$k_{nl} = 1$ (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)

```

fc' = 15.00, but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 1.2485E+008
Vu = 2.2161626E-006
d = 0.8*h = 360.00
Nu = 1.5610E+006
Ag = 90000.00
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 55849.978$ 
where:
Vs1 = 55849.978 is calculated for section web, with:
d = 360.00
Av = 157079.633
fy = 444.44
s = 300.00
Vs1 is multiplied by Col1 = 0.66666667
s/d = 0.83333333
Vs2 = 0.00 is calculated for section flange, with:
d = 160.00
Av = 157079.633
fy = 444.44
s = 300.00
Vs2 is multiplied by Col2 = 0.00
s/d = 1.875
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440:  $V_s + V_f \leq 185244.312$ 
bw = 200.00
-----

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At local axis: 3
-----

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rdc's

Constant Properties
-----
Knowledge Factor,  $\phi = 1.00$ 
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 15.00$ 
Existing material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 444.44$ 
Concrete Elasticity,  $E_c = 18203.022$ 
Steel Elasticity,  $E_s = 200000.00$ 
#####
Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength,  $f_s = 1.25*f_{sm} = 555.55$ 
#####
Max Height,  $H_{max} = 450.00$ 
Min Height,  $H_{min} = 200.00$ 
Max Width,  $W_{max} = 450.00$ 
Min Width,  $W_{min} = 200.00$ 
Cover Thickness,  $c = 25.00$ 
Mean Confinement Factor overall section = 1.00
Element Length,  $L = 3000.00$ 
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ( $l_o/l_{ou,min} \geq 1$ )
No FRP Wrapping

```

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = -5.2893364E-006$

EDGE -B-

Shear Force, $V_b = 5.2893364E-006$

BOTH EDGES

Axial Force, $F = -1.5610E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 716.2831$

-Compression: $As_c = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1746.726$

-Compression: $As_{l,com} = 829.3805$

-Middle: $As_{l,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.8353$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 303967.895$
with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 4.5595E+008$

$Mu_{1+} = 2.0582E+008$, 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

$Mu_{1-} = 4.5595E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 4.5595E+008$

$Mu_{2+} = 2.0582E+008$, 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

$Mu_{2-} = 4.5595E+008$, 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:

$\phi_u = 9.8367160E-006$

$M_u = 2.0582E+008$

with full section properties:

$b = 200.00$

$d = 407.00$

$d' = 43.00$

$v = 1.27847$

$N = 1.5610E+006$

$f_c = 15.00$

$\alpha = 0.002$ (5A.5, TBDY)

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0035$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.0035$

$\phi_{we} = 0.00$

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.00$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh_{min} = \min(psh_x, psh_y) = 0.0019822$

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)

 $psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

L_{stir} (Length of stirrups along Y) = 1060.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

 $psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

L_{stir} (Length of stirrups along X) = 1060.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

 $s = 300.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.002$

c = confinement factor = 1.00

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$su_1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$suv = 0.032$

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 $fsy_v = fs_v/1.2$, from table 5.1, TBDY
For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $f_{sv} = f_{sv}/1.2$, 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, ASCE 41-17.
 with $f_{sv} = f_s = 555.55$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.79475296$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.37736471$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.7032706$

and confined core properties:

$b = 140.00$
 $d = 377.00$
 $d' = 13.00$
 $f_{cc} \text{ (5A.2, TBDY)} = 15.00$
 $cc \text{ (5A.5, TBDY)} = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 1.22571$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.58199105$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 1.08462$

Case/Assumption: Unconfined full section - Steel rupture
 ' does not satisfy Eq. (4.3)

--->
 $v < v_{s,c}$ - RHS eq.(4.5) is not satisfied

Case/Assumption Rejected.

New Case/Assumption: Unconfined full section - Spalling of concrete cover
 ' satisfies Eq. (4.4)

--->
 $v < s_{y1}$ - LHS eq.(4.7) is not satisfied
 --->
 $v < v_{c,y1}$ - RHS eq.(4.6) is not satisfied

--->
 $cu \text{ (4.11)} = 0.87422556$
 $M_{Rc} \text{ (4.18)} = 2.0582E+008$

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 not satisfied

--->
 $*cu \text{ (4.11)} = 1.00$
 $M_{Ro} \text{ (4.18)} = 1.2754E+008$
 $M_{Ro} < 0.8 \cdot M_{Rc}$

--->
 $u = cu \text{ (unconfined full section)} = 9.8367160E-006$
 $M_u = M_{Rc}$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Mu1-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.6866617E-005$$

$$\mu_u = 4.5595E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$\nu = 0.5682084$$

$$N = 1.5610E+006$$

$$f_c = 15.00$$

$$c_o(5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.0035$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \mu_u = 0.0035$$

$$\mu_{ue} (5.4c) = 0.00$$

$$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$\mu_{sh,min} = \text{Min}(\mu_{sh,x}, \mu_{sh,y}) = 0.0019822$$

Expression ((5.4d), TB DY) for $\mu_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\mu_{sh,x} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1060.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 140000.00$$

$$\mu_{sh,y} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

$$L_{stir} (\text{Length of stirrups along X}) = 1060.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 140000.00$$

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \mu_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_1_{nominal} ((5.5), \text{TB DY}) = 0.032$$

From table 5A.1, TB DY: $esu_1_{nominal} = 0.08$,

For calculation of $esu_1_{nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TB DY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs_1 = fs = 555.55$$

```

    with Es1 = Es = 200000.00
    y2 = 0.00231479
    sh2 = 0.008
    ft2 = 666.66
    fy2 = 555.55
    su2 = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 1.00
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
    with fs2 = fs = 555.55
    with Es2 = Es = 200000.00
    yv = 0.00231479
    shv = 0.008
    ftv = 666.66
    fyv = 555.55
    suv = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/ld = 1.00
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
    with fsv = fs = 555.55
    with Esv = Es = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.16771765
    2 = Asl,com/(b*d)*(fs2/fc) = 0.35322354
    v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
    and confined core properties:
    b = 390.00
    d = 377.00
    d' = 13.00
    fcc (5A.2, TBDY) = 15.00
    cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
    2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
    v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
    Case/Assumption: Unconfined full section - Steel rupture
    ' does not satisfy Eq. (4.3)
    --->
    v < vs,c - RHS eq.(4.5) is not satisfied
    --->
    Case/Assumption Rejected.
    --->
    New Case/Assumption: Unconfined full section - Spalling of concrete cover
    ' satisfies Eq. (4.4)
    --->
    v < sy1 - LHS eq.(4.7) is not satisfied
    --->
    v < vc,y1 - RHS eq.(4.6) is satisfied
    --->
    cu (4.10) = 0.5098538
    MRc (4.17) = 4.5595E+008
    --->
    New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
    In expressions below, the following modifications have been made
    - b, d, d' replaced by geometric parameters of the core: bo, do, d'o

```

- N_1, N_2 v normalised to $b_o \cdot d_o$, instead of $b \cdot d$
- parameters of confined concrete, f_{cc} , ϵ_{cc} , used in lieu of f_c , ϵ_{cu}

---->

Subcase: Rupture of tension steel

---->

$v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->

$v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

---->

Subcase rejected

---->

New Subcase: Failure of compression zone

---->

$v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

---->

$v^* < v^*_{c,y1}$ - RHS eq.(4.6) is not satisfied

---->

ϵ^*_{cu} (4.11) = 0.56860508

M_{Ro} (4.18) = 3.5813E+008

$M_{Ro} < 0.8 \cdot M_{Rc}$

---->

ϵ_u = ϵ_{cu} (unconfined full section) = 1.6866617E-005

$\mu_u = \mu_{Rc}$

Calculation of ratio I_b/I_d

Adequate Lap Length: $I_b/I_d \geq 1$

Calculation of μ_{u2+}

Calculation of ultimate curvature ϵ_u according to 4.1, Biskinis/Fardis 2013:

$\epsilon_u = 9.8367160E-006$

$\mu_u = 2.0582E+008$

with full section properties:

$b = 200.00$

$d = 407.00$

$d' = 43.00$

$v = 1.27847$

$N = 1.5610E+006$

$f_c = 15.00$

ϵ_{co} (5A.5, TBDY) = 0.002

Final value of ϵ_{cu} : $\epsilon_{cu}^* = \text{shear_factor} \cdot \text{Max}(\epsilon_{cu}, \epsilon_{cc}) = 0.0035$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\epsilon_{cu} = 0.0035$

ϵ_{we} (5.4c) = 0.00

$\epsilon_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.00$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$\epsilon_{psh,min} = \text{Min}(\epsilon_{psh,x}, \epsilon_{psh,y}) = 0.0019822$

Expression ((5.4d), TBDY) for $\epsilon_{psh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.0019822$$

$$Lstir \text{ (Length of stirrups along Y)} = 1060.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 140000.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.0019822$$

$$Lstir \text{ (Length of stirrups along X)} = 1060.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 140000.00$$

$$s = 300.00$$

$$fywe = 555.55$$

$$fce = 15.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 1.00$$

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = fs = 555.55$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00231479$$

$$sh2 = 0.008$$

$$ft2 = 666.66$$

$$fy2 = 555.55$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 1.00$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = fs = 555.55$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00231479$$

$$shv = 0.008$$

$$ftv = 666.66$$

$$fyv = 555.55$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 1.00$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fsv = fs = 555.55$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.79475296$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.37736471$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.7032706$$

and confined core properties:

$$b = 140.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 15.00$$

$$cc (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 1.22571$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.58199105$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 1.08462$$

Case/Assumption: Unconfined full section - Steel rupture

' does not satisfy Eq. (4.3)

---->

$v < v_{s,c}$ - RHS eq.(4.5) is not satisfied

---->

Case/Assumption Rejected.

---->

New Case/Assumption: Unconfined full section - Spalling of concrete cover

' satisfies Eq. (4.4)

---->

$v < s_{y1}$ - LHS eq.(4.7) is not satisfied

---->

$v < v_{c,y1}$ - RHS eq.(4.6) is not satisfied

---->

$$cu (4.11) = 0.87422556$$

$$MRc (4.18) = 2.0582E+008$$

---->

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: b_o , d_o , d'_o
- N_1 , N_2 , v normalised to b_o*d_o , instead of $b*d$
- parameters of confined concrete, f_{cc} , 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 not satisfied

---->

$$*cu (4.11) = 1.00$$

$$MRo (4.18) = 1.2754E+008$$

$$MRo < 0.8*MRc$$

---->

$$u = cu (\text{unconfined full section}) = 9.8367160E-006$$

$$Mu = MRc$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Mu_2 -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.6866617E-005$$

$$\mu = 4.5595E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.5682084$$

$$N = 1.5610E+006$$

$$f_c = 15.00$$

$$\phi (5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \phi: \phi^* = \text{shear_factor} * \text{Max}(\phi, \phi_c) = 0.0035$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \phi = 0.0035$$

$$\phi_w (5.4c) = 0.00$$

$$\phi_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b^2/6$ as defined at (A.2).

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.0019822$$

Expression ((5.4d), TB DY) for $\phi_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\phi_{sh,x} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1060.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 140000.00$$

$$\phi_{sh,y} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

$$L_{stir} (\text{Length of stirrups along X}) = 1060.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 140000.00$$

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \phi_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} ((5.5), \text{TB DY}) = 0.032$$

$$\text{From table 5A.1, TB DY: } esu_{1,nominal} = 0.08,$$

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TB DY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs_1 = fs = 555.55$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 1.00$
 $\phi_{su2} = 0.4 * \phi_{su2,nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $\phi_{su2,nominal} = 0.08$,
For calculation of $\phi_{su2,nominal}$ and ϕ_{y2} , ϕ_{sh2} , ϕ_{ft2} , ϕ_{fy2} , it is considered
characteristic value $\phi_{sy2} = \phi_{s2}/1.2$, from table 5.1, TBDY.
 ϕ_{y1} , ϕ_{sh1} , ϕ_{ft1} , ϕ_{fy1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
with $\phi_{s2} = \phi_s = 555.55$
with $E_{s2} = E_s = 200000.00$
 $\phi_{yv} = 0.00231479$
 $\phi_{shv} = 0.008$
 $\phi_{ftv} = 666.66$
 $\phi_{fyv} = 555.55$
 $\phi_{suv} = 0.032$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 1.00$
 $\phi_{suv} = 0.4 * \phi_{suv,nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $\phi_{suv,nominal} = 0.08$,
considering characteristic value $\phi_{syv} = \phi_{sv}/1.2$, from table 5.1, TBDY
For calculation of $\phi_{suv,nominal}$ and ϕ_{yv} , ϕ_{shv} , ϕ_{ftv} , ϕ_{fyv} , it is considered
characteristic value $\phi_{syv} = \phi_{sv}/1.2$, from table 5.1, TBDY.
 ϕ_{y1} , ϕ_{sh1} , ϕ_{ft1} , ϕ_{fy1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
with $\phi_{sv} = \phi_s = 555.55$
with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b * d) * (\phi_{s1}/\phi_c) = 0.16771765$
 $2 = A_{sl,com}/(b * d) * (\phi_{s2}/\phi_c) = 0.35322354$
 $v = A_{sl,mid}/(b * d) * (\phi_{sv}/\phi_c) = 0.31256471$
and confined core properties:
 $b = 390.00$
 $d = 377.00$
 $d' = 13.00$
 $\phi_{cc} (5A.2, TBDY) = 15.00$
 $\phi_{cc} (5A.5, TBDY) = 0.002$
 $\phi_c = \text{confinement factor} = 1.00$
 $1 = A_{sl,ten}/(b * d) * (\phi_{s1}/\phi_c) = 0.20891986$
 $2 = A_{sl,com}/(b * d) * (\phi_{s2}/\phi_c) = 0.4399979$
 $v = A_{sl,mid}/(b * d) * (\phi_{sv}/\phi_c) = 0.38935066$
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
 $v < v_{s,c}$ - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
 $v < s_{y1}$ - LHS eq.(4.7) is not satisfied
--->
 $v < v_{c,y1}$ - RHS eq.(4.6) is satisfied
--->
 $\phi_{cu} (4.10) = 0.5098538$
 $M_{Rc} (4.17) = 4.5595E+008$
--->
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 $b * d$
- ϕ_c parameters of confined concrete, ϕ_{cc} , used in lieu of ϕ_c , ϕ_{cu}
--->
Subcase: Rupture of tension steel
--->
 $v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied
--->

$v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

$v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

--->

$v^* < v^*_{c,y1}$ - RHS eq.(4.6) is not satisfied

--->

ϕ_{cu} (4.11) = 0.56860508

M_{Ro} (4.18) = 3.5813E+008

$M_{Ro} < 0.8 \cdot M_{Rc}$

--->

$u = \phi_{cu}$ (unconfined full section) = 1.6866617E-005

$\mu_u = M_{Rc}$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 165623.448$

Calculation of Shear Strength at edge 1, $V_{r1} = 165623.448$

$V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $\phi_{nl} \cdot V_{ColO}$

$V_{ColO} = 165623.448$

$\phi_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + \phi_{nl} V_f$ '

where V_f is the contribution of FRPs ((11.3), ACI 440).

$\phi_{nl} = 1$ (normal-weight concrete)

$f'_c = 15.00$, but $f'_c^{0.5} \leq 8.3$ MPa ((22.5.3.1), ACI 318-14)

$M/V_d = 4.00$

$\mu_u = 1.4432E+008$

$V_u = 5.2893364E-006$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.5610E+006$

$A_g = 90000.00$

From ((11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

V_{s1} is multiplied by $\phi_{nl} = 0.00$

$s/d = 1.875$

$V_{s2} = 55849.978$ is calculated for section flange, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

V_{s2} is multiplied by $\phi_{nl} = 0.66666667$

$s/d = 0.83333333$

V_f ((11-3)-(11.4), ACI 440) = 0.00

From ((11-11), ACI 440: $V_s + V_f \leq 185244.312$

$b_w = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 165623.448$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $\phi_{nl} \cdot V_{ColO}$

$V_{ColO} = 165623.448$

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' = 15.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 1.2049E+008

Vu = 5.2893364E-006

d = 0.8*h = 360.00

Nu = 1.5610E+006

Ag = 90000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 55849.978

where:

Vs1 = 0.00 is calculated for section web, with:

d = 160.00

Av = 157079.633

fy = 444.44

s = 300.00

Vs1 is multiplied by Col1 = 0.00

s/d = 1.875

Vs2 = 55849.978 is calculated for section flange, with:

d = 360.00

Av = 157079.633

fy = 444.44

s = 300.00

Vs2 is multiplied by Col2 = 0.66666667

s/d = 0.83333333

Vf ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: Vs + Vf <= 185244.312

bw = 200.00

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1
At local axis: 2
Integration Section: (a)
Section Type: rdcs

Constant Properties

Knowledge Factor, = 1.00

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, fc = fcm = 15.00

Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44

Concrete Elasticity, Ec = 18203.022

Steel Elasticity, Es = 200000.00

Max Height, Hmax = 450.00

Min Height, Hmin = 200.00

Max Width, Wmax = 450.00

Min Width, Wmin = 200.00

Cover Thickness, c = 25.00

Element Length, L = 3000.00

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($lb/d \geq 1$)

No FRP Wrapping

Stepwise Properties

Bending Moment, $M = -3.0515\text{E}+008$

Shear Force, $V2 = 203511.132$

Shear Force, $V3 = 0.05075246$

Axial Force, $F = -1.5625\text{E}+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 1545.664$

-Compression: $As_c = 2576.106$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 829.3805$

-Compression: $As_{c,com} = 1746.726$

-Middle: $As_{mid} = 1545.664$

Mean Diameter of Tension Reinforcement, $Db_L = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = \quad * u = 0.02445888$

$u = y + p = 0.02445888$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.02445888$ ((4.29), Biskinis Phd))

$M_y = 3.4090\text{E}+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 6000.00

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 2.7875\text{E}+013$

factor = 0.70

$A_g = 140000.00$

$f_c' = 15.00$

$N = 1.5625\text{E}+006$

$E_c * I_g = 3.9822\text{E}+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

Assuming neutral axis out of flange ($y > t/d$, compression zone NOT rectangular)
extended expressions (2.1)-(2.7) of Biskinis-Fardis (2009) are adopted with:

flange width, $b = 450.00$

web width, $b_w = 200.00$

flange thickness, $t = 200.00$

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 1.0246803\text{E}-005$

with $f_y = 444.44$

$d = 407.00$

$y = 0.46715567$

$A = 0.14973202$

$B = 0.07987948$

with $p_t = 0.0019822$

$p_c = 0.00953713$

$p_v = 0.00843933$

$N = 1.5625\text{E}+006$

$b = 450.00$

" = 0.10565111

$y_{comp} = 6.6375136\text{E}-006$

with $f_c = 15.00$

$E_c = 18203.022$

$y = 0.54906081$

$A = 0.04183593$

B = 0.03668953
with Es = 200000.00
CONFIRMATION: $y = 0.54906081 > t/d$

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 not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
shear control ratio $V_y E / V_{col} E = 1.8353$

$d = 407.00$

$s = 100.00$

$t = A_v / (b_w \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = A_v \cdot L_{stir} / (A_g \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.0019822$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 1060.00$, is the total Length of all stirrups parallel to loading (shear) direction

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ is implemented to account for FRP contribution

where $f = 2 \cdot t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

$N_{UD} = 1.5625E+006$

$A_g = 140000.00$

$f_{cE} = 15.00$

$f_{ytE} = f_{ylE} = 444.44$

$\rho_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.02250488$

$b = 450.00$

$d = 407.00$

$f_{cE} = 15.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 11

column C1, Floor 1

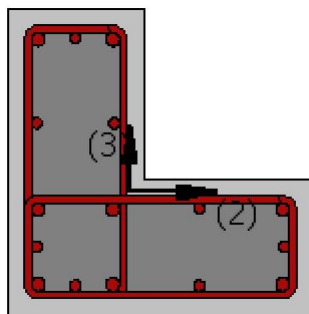
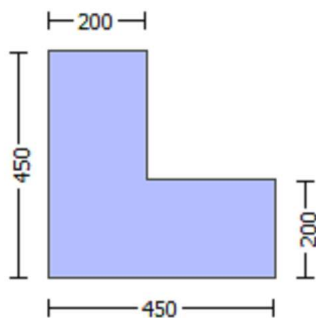
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcls

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 10.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 18203.022$

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, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 15.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

Max Height, $H_{max} = 450.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 450.00$

Min Width, $W_{min} = 200.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou,min} = l_b/l_d \geq 1$)

No FRP Wrapping

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -3.0515E+008$

Shear Force, $V_a = 0.05075246$

EDGE -B-

Bending Moment, $M_b = 1.2511E+008$

Shear Force, $V_b = -0.05075246$

BOTH EDGES

Axial Force, $F = -1.5625E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 1545.664$

-Compression: $As_c = 2576.106$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{l,ten} = 829.3805$

-Compression: $A_{sl,com} = 1746.726$

-Middle: $A_{sl,mid} = 1545.664$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = V_n = 148584.633$

V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoIO} = 148584.633$

$V_{CoI} = 148584.633$

$k_n = 1.00$

displacement_ductility_demand = 1.57246

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)

$f_c' = 10.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/V_d = 4.00$

$M_u = 3.0515E+008$

$V_u = 0.05075246$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.5625E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 50265.482$

where:

$V_{s1} = 50265.482$ is calculated for section web, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 300.00$

V_{s1} is multiplied by $Col1 = 0.66666667$

$s/d = 0.83333333$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 300.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.875$

V_f ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: $V_s + V_f \leq 151251.347$

$b_w = 200.00$

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 $\theta = 0.03846068$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.02445888$ ((4.29), Biskinis Phd))

$M_y = 3.4090E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 6000.00

From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 2.7875E+013$

factor = 0.70

$A_g = 140000.00$

$f_c' = 15.00$

$N = 1.5625E+006$

$E_c \cdot I_g = 3.9822E+013$

Calculation of Yielding Moment M_y

Calculation of ϕ and M_y according to Annex 7 -

Assuming neutral axis out of flange ($y > t/d$, compression zone NOT rectangular)
extended expressions (2.1)-(2.7) of Biskinis-Fardis (2009) are adopted with:
flange width, $b = 450.00$
web width, $b_w = 200.00$
flange thickness, $t = 200.00$

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 1.0246803\text{E-}005$
with $f_y = 444.44$
 $d = 407.00$
 $y = 0.46715567$
 $A = 0.14973202$
 $B = 0.07987948$
with $p_t = 0.00452842$
 $p_c = 0.00953713$
 $p_v = 0.00843933$
 $N = 1.5625\text{E+}006$
 $b = 450.00$
 $" = 0.10565111$
 $y_{\text{comp}} = 6.6375136\text{E-}006$
with $f_c = 15.00$
 $E_c = 18203.022$
 $y = 0.54906081$
 $A = 0.04183593$
 $B = 0.03668953$
with $E_s = 200000.00$
CONFIRMATION: $y = 0.54906081 > t/d$

Calculation of ratio I_b/I_d

Adequate Lap Length: $I_b/I_d \geq 1$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1
At local axis: 3
Integration Section: (a)

Calculation No. 12

column C1, Floor 1

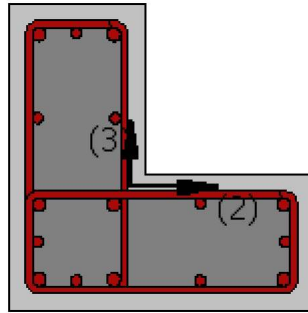
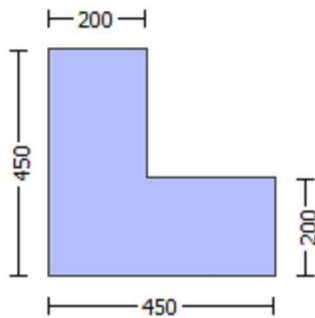
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

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: rccls

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 15.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height, $H_{max} = 450.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 450.00$

Min Width, $W_{min} = 200.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou, min} \geq 1$)

No FRP Wrapping

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 2.2161626E-006$

EDGE -B-

Shear Force, $V_b = -2.2161626E-006$

BOTH EDGES

Axial Force, $F = -1.5610E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 716.2831$

-Compression: $As_c = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t, ten} = 829.3805$

-Compression: $As_{c, com} = 1746.726$

-Middle: $As_{l, mid} = 1545.664$

Calculation of Shear Capacity ratio , $V_e/V_r = 1.8353$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 303967.895$
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 4.5595\text{E}+008$

$\mu_{1+} = 4.5595\text{E}+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{1-} = 2.0582\text{E}+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 4.5595\text{E}+008$

$\mu_{2+} = 4.5595\text{E}+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 2.0582\text{E}+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of μ_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.6866617\text{E}-005$

$M_u = 4.5595\text{E}+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.5682084$

$N = 1.5610\text{E}+006$

$f_c = 15.00$

$\phi_{co} (5A.5, \text{TBDY}) = 0.002$

Final value of ϕ_{cu} : $\phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.0035$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_{cu} = 0.0035$

$\phi_{we} (5.4c) = 0.00$

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.00$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$\phi_{psh,min} = \text{Min}(\phi_{psh,x}, \phi_{psh,y}) = 0.0019822$

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)

$\phi_{psh,x} ((5.4d), \text{TBDY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

L_{stir} (Length of stirrups along Y) = 1060.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$\phi_{psh,y} ((5.4d), \text{TBDY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

L_{stir} (Length of stirrups along X) = 1060.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$s = 300.00$

$f_{ywe} = 555.55$

```

fce = 15.00
From ((5A.5), TBDY), TBDY: cc = 0.002
c = confinement factor = 1.00
y1 = 0.00231479
sh1 = 0.008
ft1 = 666.66
fy1 = 555.55
su1 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 1.00
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fs1 = fs = 555.55
with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16771765
2 = Asl,com/(b*d)*(fs2/fc) = 0.35322354
v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)

```

```

---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
'satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.5098538
MRc (4.17) = 4.5595E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N1, N2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.56860508
MRo (4.18) = 3.5813E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 1.6866617E-005
Mu = MRc

```

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 = 9.8367160E-006

Mu = 2.0582E+008

with full section properties:

```

b = 200.00
d = 407.00
d' = 43.00
v = 1.27847
N = 1.5610E+006
fc = 15.00
co (5A.5, TBDY) = 0.002
Final value of cu* = shear_factor * Max( cu, cc) = 0.0035
The Shear_factor is considered equal to 1 (pure moment strength)

```

From (5.4b), TBDY: $c_u = 0.0035$
 w_e (5.4c) = 0.00
 $a_s = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.00$
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.
 $A_{\text{conf,max}} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{\text{conf,min}} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max}}$ by a length equal to half the clear spacing between hoops.
 $A_{\text{noConf}} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.0019822$
Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}$ ((5.4d), TBDY) = $L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.0019822$
 L_{stir} (Length of stirrups along Y) = 1060.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 140000.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.0019822$
 L_{stir} (Length of stirrups along X) = 1060.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 140000.00

$s = 300.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.002$
 c = confinement factor = 1.00

$y_1 = 0.00231479$
 $sh_1 = 0.008$
 $ft_1 = 666.66$
 $fy_1 = 555.55$
 $su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$su_1 = 0.4 * esu_{1,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$
 $sh_2 = 0.008$
 $ft_2 = 666.66$
 $fy_2 = 555.55$
 $su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 * esu_{2,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2 , sh_2 , ft_2 , fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2 , sh_2 , ft_2 , fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$
 $sh_v = 0.008$

```

ftv = 666.66
fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/ld = 1.00
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
    with fsv = fs = 555.55
    with Esv = Es = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.79475296
    2 = Asl,com/(b*d)*(fs2/fc) = 0.37736471
    v = Asl,mid/(b*d)*(fsv/fc) = 0.7032706
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
    2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
    v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008

```

$$M_{Ro} < 0.8 \cdot M_{Rc}$$

--->

$$u = c_u \text{ (unconfined full section)} = 9.8367160E-006$$

$$M_u = M_{Rc}$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of M_{u2+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 1.6866617E-005$$

$$M_u = 4.5595E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.5682084$$

$$N = 1.5610E+006$$

$$f_c = 15.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0035$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0035$$

$$w_e \text{ (5.4c)} = 0.00$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.0019822$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1060.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 140000.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1060.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 140000.00$$

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$f_{t1} = 666.66$$

$$f_{y1} = 555.55$$

```

su1 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fs1 = fs = 555.55
with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16771765
2 = Asl,com/(b*d)*(fs2/fc) = 0.35322354
v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)

```



```

---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.5098538
MRc (4.17) = 4.5595E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu

```

```

---->
Subcase: Rupture of tension steel

```

```

---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied

```

```

---->
v* < v*s,c - LHS eq.(4.5) is not satisfied

```

```

---->
Subcase rejected

```

```

---->
New Subcase: Failure of compression zone

```

```

---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied

```

```

---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied

```

```

---->
*cu (4.11) = 0.56860508
MRo (4.18) = 3.5813E+008
MRo < 0.8*MRc

```

```

---->
u = cu (unconfined full section) = 1.6866617E-005
Mu = MRc

```

```

-----
Calculation of ratio lb/d

```

```

-----
Adequate Lap Length: lb/d >= 1

```

```

-----
Calculation of Mu2-

```

```

-----
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

```

```

u = 9.8367160E-006
Mu = 2.0582E+008

```

```

-----
with full section properties:

```

```

b = 200.00
d = 407.00
d' = 43.00
v = 1.27847
N = 1.5610E+006
fc = 15.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.0035
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.0035
we (5.4c) = 0.00
ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.00
The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization
of the rectangular sections confinement, which is expressed by (5.4d).
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)
"Theoretical Stress-Strain Model for Confined Concrete."

```

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max = 89600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

Aconf,min = 0.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 54733.333 is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.0019822

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) = 0.0019822

Lstir (Length of stirrups along Y) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.0019822

Lstir (Length of stirrups along X) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

s = 300.00

fywe = 555.55

fce = 15.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

```

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.79475296
2 = Asl,com/(b*d)*(fs2/fc) = 0.37736471
v = Asl,mid/(b*d)*(fsv/fc) = 0.7032706
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 9.8367160E-006
Mu = MRc
-----

```

Calculation of ratio lb/ld

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 165623.448$

Calculation of Shear Strength at edge 1, $V_{r1} = 165623.448$

$V_{r1} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_n l^* V_{\text{Col}0}$

$V_{\text{Col}0} = 165623.448$

$k_n l = 1$ (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)

$f'_c = 15.00$, but $f_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.4825 \times 10^8$

$\nu_u = 2.2161626 \times 10^6$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.5610 \times 10^6$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$

where:

$V_{s1} = 55849.978$ is calculated for section web, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

V_{s1} is multiplied by $\text{Col}1 = 0.66666667$

$s/d = 0.83333333$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

V_{s2} is multiplied by $\text{Col}2 = 0.00$

$s/d = 1.875$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 0.00$

From (11-11), ACI 440: $V_s + V_f \leq 185244.312$

$b_w = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 165623.448$

$V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_n l^* V_{\text{Col}0}$

$V_{\text{Col}0} = 165623.448$

$k_n l = 1$ (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)

$f'_c = 15.00$, but $f_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.2485 \times 10^8$

$\nu_u = 2.2161626 \times 10^6$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.5610 \times 10^6$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$

where:

$V_{s1} = 55849.978$ is calculated for section web, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$
 V_{s1} is multiplied by $Col1 = 0.66666667$
 $s/d = 0.83333333$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 160.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 300.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.875$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
 From $(11-11)$, ACI 440: $V_s + V_f \leq 185244.312$
 $bw = 200.00$

 End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
 At local axis: 3

 Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rdcS

Constant Properties

 Knowledge Factor, $\phi = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 15.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 18203.022$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$
 #####
 Max Height, $H_{max} = 450.00$
 Min Height, $H_{min} = 200.00$
 Max Width, $W_{max} = 450.00$
 Min Width, $W_{min} = 200.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.00
 Element Length, $L = 3000.00$
 Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{ou}, \min > 1$)
 No FRP Wrapping

Stepwise Properties

 At local axis: 2
 EDGE -A-
 Shear Force, $V_a = -5.2893364E-006$
 EDGE -B-
 Shear Force, $V_b = 5.2893364E-006$
 BOTH EDGES
 Axial Force, $F = -1.5610E+006$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 716.2831$

-Compression: $Asl_c = 3091.327$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $Asl_{ten} = 1746.726$
 -Compression: $Asl_{com} = 829.3805$
 -Middle: $Asl_{mid} = 1545.664$

Calculation of Shear Capacity ratio , $V_e/V_r = 1.8353$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 303967.895$
 with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 4.5595E+008$

$\mu_{1+} = 2.0582E+008$, 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

$\mu_{1-} = 4.5595E+008$, 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 4.5595E+008$

$\mu_{2+} = 2.0582E+008$, 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

$\mu_{2-} = 4.5595E+008$, 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:

$\mu = 9.8367160E-006$

$\mu_u = 2.0582E+008$

with full section properties:

$b = 200.00$

$d = 407.00$

$d' = 43.00$

$v = 1.27847$

$N = 1.5610E+006$

$f_c = 15.00$

ϕ_o (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_o) = 0.0035$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.0035$

we (5.4c) = 0.00

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.00$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.0019822$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

L_{stir} (Length of stirrups along Y) = 1060.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$\phi_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

Lstir (Length of stirrups along X) = 1060.00
Astir (stirrups area) = 78.53982
Asec (section area) = 140000.00

s = 300.00

fywe = 555.55

fce = 15.00

From ((5.A.5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.79475296

2 = Asl,com/(b*d)*(fs2/fc) = 0.37736471

v = Asl,mid/(b*d)*(fsv/fc) = 0.7032706

and confined core properties:

b = 140.00

d = 377.00

d' = 13.00

fcc (5A.2, TBDY) = 15.00

cc (5A.5, TBDY) = 0.002

```

c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is not satisfied
--->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
--->
v* < v*sc - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
--->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
--->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008
MRo < 0.8*MRc
--->
u = cu (unconfined full section) = 9.8367160E-006
Mu = MRc
-----

Calculation of ratio lb/d
-----
Adequate Lap Length: lb/d >= 1
-----
-----

Calculation of Mu1-
-----
-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.6866617E-005
Mu = 4.5595E+008
-----

with full section properties:
b = 450.00
d = 407.00
d' = 43.00

```


$v = 0.5682084$
 $N = 1.5610E+006$
 $f_c = 15.00$
 $\alpha (5A.5, TBDY) = 0.002$
 Final value of α : $\alpha = \text{shear_factor} * \text{Max}(\alpha_c, \alpha_s) = 0.0035$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\alpha_c = 0.0035$
 $\alpha_s (5.4c) = 0.00$
 $\alpha_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$
 The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
 $A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.
 $A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $\alpha_{sh,min} = \text{Min}(\alpha_{sh,x}, \alpha_{sh,y}) = 0.0019822$
 Expression ((5.4d), TBDY) for $\alpha_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\alpha_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$
 L_{stir} (Length of stirrups along Y) = 1060.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 140000.00

$\alpha_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$
 L_{stir} (Length of stirrups along X) = 1060.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 140000.00

$s = 300.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 15.00$
 From ((5.A.5), TBDY), TBDY: $\alpha_c = 0.002$
 α_c = confinement factor = 1.00
 $\gamma_1 = 0.00231479$
 $\gamma_{sh1} = 0.008$
 $f_{t1} = 666.66$
 $f_{y1} = 555.55$
 $\gamma_{su1} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $\gamma_{lo/\gamma_{ou,min}} = \gamma_{lb/\gamma_{ld}} = 1.00$
 $\gamma_{su1} = 0.4 * \gamma_{su1_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $\gamma_{su1_nominal} = 0.08$,
 For calculation of $\gamma_{su1_nominal}$ and $\gamma_1, \gamma_{sh1}, f_{t1}, f_{y1}$, it is considered characteristic value $f_{sy1} = f_{s1}/1.2$, from table 5.1, TBDY.
 $\gamma_1, \gamma_{sh1}, f_{t1}, f_{y1}$, are also multiplied by $\text{Min}(1, 1.25 * (\gamma_{lb}/\gamma_{ld})^{2/3})$, from 10.3.5, ASCE 41-17.
 with $f_{s1} = f_s = 555.55$
 with $E_{s1} = E_s = 200000.00$
 $\gamma_2 = 0.00231479$
 $\gamma_{sh2} = 0.008$
 $f_{t2} = 666.66$
 $f_{y2} = 555.55$
 $\gamma_{su2} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $\gamma_{lo/\gamma_{ou,min}} = \gamma_{lb/\gamma_{lb,min}} = 1.00$
 $\gamma_{su2} = 0.4 * \gamma_{su2_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $\gamma_{su2_nominal} = 0.08$,
 For calculation of $\gamma_{su2_nominal}$ and $\gamma_2, \gamma_{sh2}, f_{t2}, f_{y2}$, it is considered

```

characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.
 $y_1, sh_1, ft_1, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.
with  $f_{s2} = f_s = 555.55$ 
with  $E_{s2} = E_s = 200000.00$ 
 $y_v = 0.00231479$ 
 $sh_v = 0.008$ 
 $ft_v = 666.66$ 
 $f_{y_v} = 555.55$ 
 $s_{u_v} = 0.032$ 
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
 $l_o/l_{o,min} = l_b/l_d = 1.00$ 
 $s_{u_v} = 0.4 \cdot e_{s_{u_v,nominal}} ((5.5), \text{TBDY}) = 0.032$ 
From table 5A.1, TBDY:  $e_{s_{u_v,nominal}} = 0.08$ ,
considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY
For calculation of  $e_{s_{u_v,nominal}}$  and  $y_v, sh_v, ft_v, f_{y_v}$ , it is considered
characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.
 $y_1, sh_1, ft_1, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.
with  $f_{sv} = f_s = 555.55$ 
with  $E_{sv} = E_s = 200000.00$ 
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.16771765$ 
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.35322354$ 
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.31256471$ 
and confined core properties:
 $b = 390.00$ 
 $d = 377.00$ 
 $d' = 13.00$ 
 $f_{cc} (5A.2, \text{TBDY}) = 15.00$ 
 $cc (5A.5, \text{TBDY}) = 0.002$ 
 $c = \text{confinement factor} = 1.00$ 
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.20891986$ 
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.4399979$ 
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.38935066$ 
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
 $v < v_{s,c}$  - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
 $v < s_{y1}$  - LHS eq.(4.7) is not satisfied
---->
 $v < v_{c,y1}$  - RHS eq.(4.6) is satisfied
---->
 $c_u (4.10) = 0.5098538$ 
 $M_{Rc} (4.17) = 4.5595E+008$ 
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
-  $b, d, d'$  replaced by geometric parameters of the core:  $b_o, d_o, d'_o$ 
-  $N, 1, 2, v$  normalised to  $b_o \cdot d_o$ , instead of  $b \cdot d$ 
-  $f_{cc}, cc$ , used in lieu of  $f_c, c_u$ 
---->
Subcase: Rupture of tension steel
---->
 $v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied
---->
 $v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->

```

$v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

--->

$v^* < v^*_{c,y1}$ - RHS eq.(4.6) is not satisfied

--->

* c_u (4.11) = 0.56860508

M_{Ro} (4.18) = 3.5813E+008

$M_{Ro} < 0.8 * M_{Rc}$

--->

$u = c_u$ (unconfined full section) = 1.6866617E-005

$\mu_u = M_{Rc}$

Calculation of ratio I_b/I_d

Adequate Lap Length: $I_b/I_d \geq 1$

Calculation of μ_{u2+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 9.8367160E-006$

$\mu_u = 2.0582E+008$

with full section properties:

$b = 200.00$

$d = 407.00$

$d' = 43.00$

$v = 1.27847$

$N = 1.5610E+006$

$f_c = 15.00$

ϕ_u (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0035$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.0035$

ϕ_{ue} (5.4c) = 0.00

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.0019822$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

L_{stir} (Length of stirrups along Y) = 1060.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$\phi_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

L_{stir} (Length of stirrups along X) = 1060.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$s = 300.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A.5), TBDY), TBDY: $cc = 0.002$
 $c = \text{confinement factor} = 1.00$
 $y1 = 0.00231479$
 $sh1 = 0.008$
 $ft1 = 666.66$
 $fy1 = 555.55$
 $su1 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 1.00$
 $su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu1_nominal = 0.08$,
 For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
 characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs1 = fs = 555.55$
 with $Es1 = Es = 200000.00$
 $y2 = 0.00231479$
 $sh2 = 0.008$
 $ft2 = 666.66$
 $fy2 = 555.55$
 $su2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/lb, \min = 1.00$
 $su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs2 = fs = 555.55$
 with $Es2 = Es = 200000.00$
 $yv = 0.00231479$
 $shv = 0.008$
 $ftv = 666.66$
 $fyv = 555.55$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 1.00$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = fs = 555.55$
 with $Esv = Es = 200000.00$
 $1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.79475296$
 $2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.37736471$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.7032706$
 and confined core properties:
 $b = 140.00$
 $d = 377.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 15.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 1.22571$
 $2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.58199105$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 1.08462$
 Case/Assumption: Unconfined full section - Steel rupture
 ' does not satisfy Eq. (4.3)

--->

```

v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
'satisfies Eq. (4.4)
--->
v < s,y1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is not satisfied
--->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
--->
v* < v*s,c - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
--->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
--->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008
MRo < 0.8*MRc
--->
u = cu (unconfined full section) = 9.8367160E-006
Mu = MRc

```

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

```

u = 1.6866617E-005
Mu = 4.5595E+008

```

with full section properties:

```

b = 450.00
d = 407.00
d' = 43.00
v = 0.5682084
N = 1.5610E+006
fc = 15.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.0035
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.0035

```

$$w_e (5.4c) = 0.00$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.0019822$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} ((5.4d), \text{TBDY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1060.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 140000.00$$

$$p_{sh,y} ((5.4d), \text{TBDY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

$$L_{stir} (\text{Length of stirrups along X}) = 1060.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 140000.00$$

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From } ((5.A5), \text{TBDY}), \text{TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_1_{nominal} ((5.5), \text{TBDY}) = 0.032$$

From table 5A.1, TBDY: $esu_1_{nominal} = 0.08$,

For calculation of $esu_1_{nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs_1 = fs = 555.55$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$$

$$su_2 = 0.4 * esu_2_{nominal} ((5.5), \text{TBDY}) = 0.032$$

From table 5A.1, TBDY: $esu_2_{nominal} = 0.08$,

For calculation of $esu_2_{nominal}$ and y_2 , sh_2 , ft_2 , fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs_2 = fs = 555.55$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

```

fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/d = 1.00
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.
    with fsv = fs = 555.55
    with Esv = Es = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.16771765
    2 = Asl,com/(b*d)*(fs2/fc) = 0.35322354
    v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
    2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
    v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
    cu (4.10) = 0.5098538
    MRc (4.17) = 4.5595E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
    - b, d, d' replaced by geometric parameters of the core: bo, do, d'o
    - N, 1, 2, v normalised to bo*do, instead of b*d
    - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
    *cu (4.11) = 0.56860508
    MRo (4.18) = 3.5813E+008
    MRo < 0.8*MRc

```

--->

$u = cu$ (unconfined full section) = 1.6866617E-005

$\mu = MRc$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 165623.448$

Calculation of Shear Strength at edge 1, $V_{r1} = 165623.448$

$V_{r1} = V_{col}$ ((10.3), ASCE 41-17) = $k_n l V_{col0}$

$V_{col0} = 165623.448$

$k_n l = 1$ (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)

$f'_c = 15.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu = 1.4432E+008$

$V_u = 5.2893364E-006$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.5610E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 1.875$

$V_{s2} = 55849.978$ is calculated for section flange, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

V_{s2} is multiplied by $Col2 = 0.66666667$

$s/d = 0.83333333$

V_f ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: $V_s + V_f \leq 185244.312$

$b_w = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 165623.448$

$V_{r2} = V_{col}$ ((10.3), ASCE 41-17) = $k_n l V_{col0}$

$V_{col0} = 165623.448$

$k_n l = 1$ (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)

$f'_c = 15.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu = 1.2049E+008$

$V_u = 5.2893364E-006$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.5610E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 1.875$

$V_{s2} = 55849.978$ is calculated for section flange, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

V_{s2} is multiplied by $Col2 = 0.66666667$

$s/d = 0.83333333$

$V_f ((11-3)-(11.4), ACI 440) = 0.00$

From (11-11), ACI 440: $V_s + V_f \leq 185244.312$

$b_w = 200.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rclcs

Constant Properties

Knowledge Factor, $= 1.00$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 15.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 450.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 450.00$

Min Width, $W_{min} = 200.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/d \geq 1$)

No FRP Wrapping

Stepwise Properties

Bending Moment, $M = 2.4684E+007$

Shear Force, $V_2 = 203511.132$

Shear Force, $V_3 = 0.05075246$

Axial Force, $F = -1.5625E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 1545.664$

-Compression: $As_c = 2576.106$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $Asl_{ten} = 1746.726$
-Compression: $Asl_{com} = 829.3805$
-Middle: $Asl_{mid} = 1545.664$

Mean Diameter of Tension Reinforcement, $DbL = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = u = 0.00052915$
 $u = y + p = 0.00052915$

- Calculation of y -

$y = (My * L_s / 3) / E_{eff} = 0.00052915$ ((4.29), Biskinis Phd))
 $My = 1.4750E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 2.7875E+013$
 $factor = 0.70$
 $Ag = 140000.00$
 $fc' = 15.00$
 $N = 1.5625E+006$
 $E_c * I_g = 3.9822E+013$

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 1.4509707E-005$
with $f_y = 444.44$
 $d = 407.00$
 $y = 0.62370357$
 $A = 0.09382593$
 $B = 0.07622229$
with $pt = 0.0019822$
 $pc = 0.01018895$
 $pv = 0.0189885$
 $N = 1.5625E+006$
 $b = 200.00$
 $" = 0.10565111$
 $y_{comp} = 3.5712582E-006$
with $fc = 15.00$
 $E_c = 18203.022$
 $y = 1.02048$
 $A = -0.01407015$
 $B = 0.03303234$
with $E_s = 200000.00$

Calculation of ratio lb/d

Adequate Lap Length: $lb/d \geq 1$

- Calculation of p -

From table 10-8: $p = 0.00$

with:

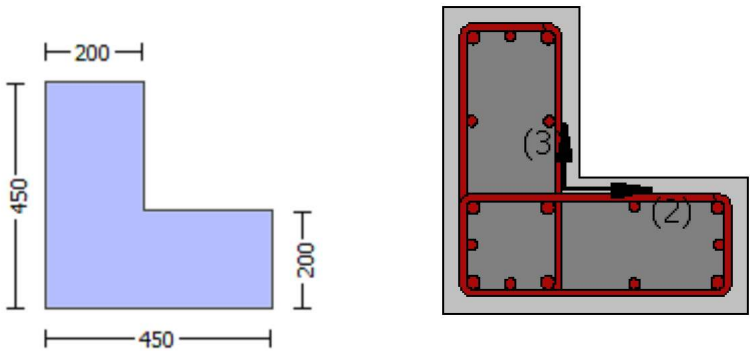
- Columns not controlled by inadequate development or splicing along the clear height because $lb/d \geq 1$
shear control ratio $V_y E / V_{col} O E = 1.8353$
 $d = 407.00$
 $s = 100.00$
 $t = A_v / (b_w * s) + 2 * t_f / b_w * (f_f / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_f / f_s) = 0.0019822$
 $A_v = 78.53982$, is the area of every stirrup

Lstir = 1060.00, is the total Length of all stirrups parallel to loading (shear) direction
The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ is implemented to account for FRP contribution
where $f = 2 \cdot t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength
All these variables have already been given in Shear control ratio calculation.
NUD = 1.5625E+006
Ag = 140000.00
fcE = 15.00
fytE = fyle = 444.44
pl = Area_Tot_Long_Rein/(b*d) = 0.05063599
b = 200.00
d = 407.00
fcE = 15.00

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1
At local axis: 3
Integration Section: (a)

Calculation No. 13

column C1, Floor 1
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)
Analysis: Uniform +X
Check: Shear capacity VRd
Edge: End
Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1
At local axis: 2
Integration Section: (b)
Section Type: rcCs

Constant Properties

Knowledge Factor, = 1.00
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 10.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
 Concrete Elasticity, $E_c = 18203.022$
 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, ASCE 41-17) because bending is considered as
 Deformation-Controlled Action (Table C7-1, ASCE 41-17).
 Existing material: Concrete Strength, $f_c = f_{cm} = 15.00$
 Existing material: Steel Strength, $f_s = f_{sm} = 444.44$
 #####
 Max Height, $H_{max} = 450.00$
 Min Height, $H_{min} = 200.00$
 Max Width, $W_{max} = 450.00$
 Min Width, $W_{min} = 200.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{ou,min} = l_b/l_d \geq 1$)
 No FRP Wrapping

Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = 2.4684E+007$
 Shear Force, $V_a = 203511.132$
 EDGE -B-
 Bending Moment, $M_b = 1.6143E+008$
 Shear Force, $V_b = -203511.132$
 BOTH EDGES
 Axial Force, $F = -1.5625E+006$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{sl,t} = 1030.442$
 -Compression: $A_{sl,c} = 3091.327$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{sl,ten} = 1746.726$
 -Compression: $A_{sl,com} = 829.3805$
 -Middle: $A_{sl,mid} = 1545.664$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 217288.685$
 V_n ((10.3), ASCE 41-17) = $k_n l V_{CoIO} = 217288.685$
 $V_{CoI} = 228756.923$
 $k_n l = 0.94986714$
 displacement_ductility_demand = 2.66844

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).

$\beta = 1$ (normal-weight concrete)
 $f_c' = 10.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.20334$
 $M_u = 1.6143E+008$
 $V_u = 203511.132$
 $d = 0.8 \cdot h = 360.00$
 $N_u = 1.5625E+006$
 $A_g = 90000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 50265.482$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$$d = 160.00$$

$$A_v = 157079.633$$

$$f_y = 400.00$$

$$s = 300.00$$

V_{s1} is multiplied by $Col1 = 0.00$

$$s/d = 1.875$$

$V_{s2} = 50265.482$ is calculated for section flange, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 400.00$$

$$s = 300.00$$

V_{s2} is multiplied by $Col2 = 0.66666667$

$$s/d = 0.83333333$$

$V_f ((11-3)-(11.4), ACI 440) = 0.00$

From (11-11), ACI 440: $V_s + V_f \leq 151251.347$

$$bw = 200.00$$

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 $\phi = 0.00373337$

$$y = (M_y * L_s / 3) / E_{eff} = 0.00139908 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 1.4750E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 793.2009$$

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 2.7875E+013$

$$factor = 0.70$$

$$A_g = 140000.00$$

$$f_c' = 15.00$$

$$N = 1.5625E+006$$

$$E_c * I_g = 3.9822E+013$$

Calculation of Yielding Moment M_y

Calculation of ϕ and M_y according to Annex 7 -

$$y = \min(y_{ten}, y_{com})$$

$$y_{ten} = 1.4509707E-005$$

with $f_y = 444.44$

$$d = 407.00$$

$$y = 0.62370357$$

$$A = 0.09382593$$

$$B = 0.07622229$$

$$\text{with } p_t = 0.02145854$$

$$p_c = 0.01018895$$

$$p_v = 0.0189885$$

$$N = 1.5625E+006$$

$$b = 200.00$$

$$r = 0.10565111$$

$$y_{comp} = 3.5712582E-006$$

with $f_c = 15.00$

$$E_c = 18203.022$$

$$y = 1.02048$$

$$A = -0.01407015$$

$$B = 0.03303234$$

$$\text{with } E_s = 200000.00$$

Calculation of ratio I_b/I_d

Adequate Lap Length: $l_b/l_d \geq 1$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 14

column C1, Floor 1

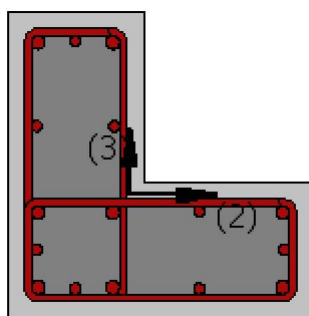
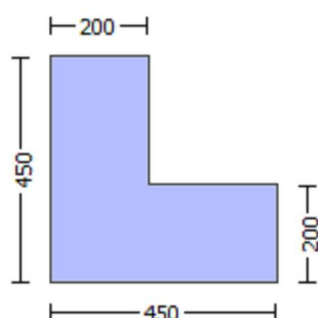
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity (μ)

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: rdc

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, $f_c = f_{cm} = 15.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height, $H_{max} = 450.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 450.00$
 Min Width, $W_{min} = 200.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.00
 Element Length, $L = 3000.00$
 Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{o,u}, \min > 1$)
 No FRP Wrapping

Stepwise Properties

At local axis: 3
 EDGE -A-
 Shear Force, $V_a = 2.2161626E-006$
 EDGE -B-
 Shear Force, $V_b = -2.2161626E-006$
 BOTH EDGES
 Axial Force, $F = -1.5610E+006$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 716.2831$
 -Compression: $As_c = 3091.327$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{t,ten} = 829.3805$
 -Compression: $As_{c,com} = 1746.726$
 -Middle: $As_{mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.8353$
 Member Controlled by Shear ($V_e/V_r > 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 303967.895$
 with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 4.5595E+008$
 $\mu_{u1+} = 4.5595E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u1-} = 2.0582E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 4.5595E+008$
 $\mu_{u2+} = 4.5595E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u2-} = 2.0582E+008$, 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_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 1.6866617E-005$
 $M_u = 4.5595E+008$

with full section properties:

$b = 450.00$
 $d = 407.00$
 $d' = 43.00$
 $v = 0.5682084$
 $N = 1.5610E+006$
 $f_c = 15.00$
 ϕ_o (5A.5, TBDY) = 0.002
 Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \max(\phi_u, \phi_o) = 0.0035$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.0035$

w_e (5.4c) = 0.00

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.0019822$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

L_{stir} (Length of stirrups along Y) = 1060.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

L_{stir} (Length of stirrups along X) = 1060.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$s = 300.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.002$

$c = \text{confinement factor} = 1.00$

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$su_1 = 0.4 * esu1_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 * esu2_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and y_2 , sh_2 , ft_2 , fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2 , sh_2 , ft_2 , fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$


```

shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/ld = 1.00
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
    with fsv = fs = 555.55
    with Esv = Es = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.16771765
    2 = Asl,com/(b*d)*(fs2/fc) = 0.35322354
    v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
    2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
    v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
    cu (4.10) = 0.5098538
MRc (4.17) = 4.5595E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
    *cu (4.11) = 0.56860508

```

$$M_{Ro} (4.18) = 3.5813E+008$$

$$M_{Ro} < 0.8 * M_{Rc}$$

--->

$$u = c_u \text{ (unconfined full section)} = 1.6866617E-005$$

$$M_u = M_{Rc}$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of M_{u1} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 9.8367160E-006$$

$$M_u = 2.0582E+008$$

with full section properties:

$$b = 200.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 1.27847$$

$$N = 1.5610E+006$$

$$f_c = 15.00$$

$$c_o (5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0035$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } c_u = 0.0035$$

$$w_e (5.4c) = 0.00$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.0019822$$

Expression ((5.4d), TB DY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1060.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 140000.00$$

$$p_{sh,y} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1060.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 140000.00$$

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From ((5.A5), TB DY), TB DY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

```

fy1 = 555.55
su1 = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/ld = 1.00
    su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu1_nominal = 0.08,
    For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
    characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
    with fs1 = fs = 555.55
    with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 1.00
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
    with fs2 = fs = 555.55
    with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/ld = 1.00
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
    with fsv = fs = 555.55
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.79475296
2 = Asl,com/(b*d)*(fs2/fc) = 0.37736471
v = Asl,mid/(b*d)*(fsv/fc) = 0.7032706
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
    2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
    v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover

```

```

satisfies Eq. (4.4)
---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 9.8367160E-006
Mu = MRc
-----

Calculation of ratio lb/ld
-----

Adequate Lap Length: lb/ld >= 1
-----

Calculation of Mu2+
-----

-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.6866617E-005
Mu = 4.5595E+008
-----

with full section properties:
b = 450.00
d = 407.00
d' = 43.00
v = 0.5682084
N = 1.5610E+006
fc = 15.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.0035
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.0035
we (5.4c) = 0.00
ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.00
The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization
of the rectangular sections confinement, which is expressed by (5.4d).
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

```

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.0019822$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.0019822$

L_{stir} (Length of stirrups along Y) = 1060.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.0019822$

L_{stir} (Length of stirrups along X) = 1060.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$s = 300.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

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

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$su_1 = 0.4 \cdot esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 \cdot esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

```

lo/lou,min = lb/d = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16771765
2 = Asl,com/(b*d)*(fs2/fc) = 0.35322354
v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.5098538
MRc (4.17) = 4.5595E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.56860508
MRo (4.18) = 3.5813E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 1.6866617E-005
Mu = MRc
-----

```

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of μ_u

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$\mu_u = 9.8367160E-006$$

$$\mu_u = 2.0582E+008$$

with full section properties:

$$b = 200.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 1.27847$$

$$N = 1.5610E+006$$

$$f_c = 15.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, c_o) = 0.0035$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.0035$$

$$\mu_{ue} \text{ (5.4c)} = 0.00$$

$$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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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$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.0019822$$

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)

$$\mu_{psh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1060.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 140000.00$$

$$\mu_{psh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1060.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 140000.00$$

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu1_nominal = 0.08$,
For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
with $fs1 = fs = 555.55$
with $Es1 = Es = 200000.00$
 $y2 = 0.00231479$
 $sh2 = 0.008$
 $ft2 = 666.66$
 $fy2 = 555.55$
 $su2 = 0.032$
using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$
and also multiplied by the $shear_factor$ according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou, min = lb/lb, min = 1.00$
 $su2 = 0.4 \cdot esu2_nominal ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esu2_nominal = 0.08$,
For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
with $fs2 = fs = 555.55$
with $Es2 = Es = 200000.00$
 $yv = 0.00231479$
 $shv = 0.008$
 $ftv = 666.66$
 $fyv = 555.55$
 $suv = 0.032$
using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$
and also multiplied by the $shear_factor$ according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou, min = lb/ld = 1.00$
 $suv = 0.4 \cdot esuv_nominal ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esuv_nominal = 0.08$,
considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
with $fsv = fs = 555.55$
with $Esv = Es = 200000.00$
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.79475296$
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.37736471$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.7032706$
and confined core properties:
 $b = 140.00$
 $d = 377.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 15.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 1.22571$
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.58199105$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 1.08462$
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
 $v < vs, c$ - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
 $v < s, y1$ - LHS eq.(4.7) is not satisfied
--->
 $v < vc, y1$ - RHS eq.(4.6) is not satisfied
--->
 $cu (4.11) = 0.87422556$

$$M_{Rc} (4.18) = 2.0582E+008$$

---->

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N_1 , N_2 , v normalised to b_o*d_o , instead of $b*d$
- parameters of confined concrete, f_{cc} , ϵ_{cc} , used in lieu of f_c , ϵ_{cu}

---->

Subcase: Rupture of tension steel

---->

$v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->

$v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

---->

Subcase rejected

---->

New Subcase: Failure of compression zone

---->

$v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

---->

$v^* < v^*_{c,y1}$ - RHS eq.(4.6) is not satisfied

---->

$$f_{cu} (4.11) = 1.00$$

$$M_{Ro} (4.18) = 1.2754E+008$$

$$M_{Ro} < 0.8*M_{Rc}$$

---->

$$u = f_{cu} \text{ (unconfined full section)} = 9.8367160E-006$$

$$M_u = M_{Rc}$$

Calculation of ratio I_b/I_d

Adequate Lap Length: $I_b/I_d \geq 1$

$$\text{Calculation of Shear Strength } V_r = \text{Min}(V_{r1}, V_{r2}) = 165623.448$$

$$\text{Calculation of Shear Strength at edge 1, } V_{r1} = 165623.448$$

$$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_n l^* V_{ColO}$$

$$V_{ColO} = 165623.448$$

$$k_n l = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+} + f^* V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$f'_c = 15.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$M_u = 1.4825E+008$$

$$V_u = 2.2161626E-006$$

$$d = 0.8*h = 360.00$$

$$N_u = 1.5610E+006$$

$$A_g = 90000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 55849.978$$

where:

$V_{s1} = 55849.978$ is calculated for section web, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 300.00$$

V_{s1} is multiplied by $Col1 = 0.66666667$

$$s/d = 0.83333333$$

$V_{s2} = 0.00$ is calculated for section flange, with:

$$d = 160.00$$

$$A_v = 157079.633$$

fy = 444.44
s = 300.00
Vs2 is multiplied by Col2 = 0.00
s/d = 1.875
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 185244.312
bw = 200.00

Calculation of Shear Strength at edge 2, Vr2 = 165623.448
Vr2 = VCol ((10.3), ASCE 41-17) = knl*VCol0
VCol0 = 165623.448
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' = 15.00, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 1.2485E+008
Vu = 2.2161626E+006
d = 0.8*h = 360.00
Nu = 1.5610E+006
Ag = 90000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 55849.978
where:
Vs1 = 55849.978 is calculated for section web, with:
d = 360.00
Av = 157079.633
fy = 444.44
s = 300.00
Vs1 is multiplied by Col1 = 0.66666667
s/d = 0.83333333
Vs2 = 0.00 is calculated for section flange, with:
d = 160.00
Av = 157079.633
fy = 444.44
s = 300.00
Vs2 is multiplied by Col2 = 0.00
s/d = 1.875
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 185244.312
bw = 200.00

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: 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 = 15.00
Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44
Concrete Elasticity, Ec = 18203.022
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, $H_{max} = 450.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 450.00$

Min Width, $W_{min} = 200.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou,min} \geq 1$)

No FRP Wrapping

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = -5.2893364E-006$

EDGE -B-

Shear Force, $V_b = 5.2893364E-006$

BOTH EDGES

Axial Force, $F = -1.5610E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 716.2831$

-Compression: $As_c = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1746.726$

-Compression: $As_{l,com} = 829.3805$

-Middle: $As_{l,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.8353$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 303967.895$

with

$M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 4.5595E+008$

$\mu_{u1+} = 2.0582E+008$, 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

$\mu_{u1-} = 4.5595E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination

$M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 4.5595E+008$

$\mu_{u2+} = 2.0582E+008$, 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

$\mu_{u2-} = 4.5595E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 9.8367160E-006$

$\mu_u = 2.0582E+008$

with full section properties:

$b = 200.00$

$d = 407.00$

$d' = 43.00$
 $v = 1.27847$
 $N = 1.5610E+006$
 $f_c = 15.00$
 $\alpha (5A.5, TBDY) = 0.002$
 Final value of α : $\alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.0035$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\alpha = 0.0035$
 $\alpha_e (5.4c) = 0.00$
 $\alpha_{se} = \text{Max}(((\alpha_{conf,max} - \alpha_{noConf}) / \alpha_{conf,max}) * (\alpha_{conf,min} / \alpha_{conf,max}), 0) = 0.00$
 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.
 $\alpha_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $\alpha_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $\alpha_{conf,max}$ by a length equal to half the clear spacing between hoops.
 $\alpha_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i d_i / 6$ as defined at (A.2).
 $\alpha_{sh,min} = \text{Min}(\alpha_{sh,x}, \alpha_{sh,y}) = 0.0019822$
 Expression ((5.4d), TBDY) for $\alpha_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\alpha_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$
 L_{stir} (Length of stirrups along Y) = 1060.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 140000.00

$\alpha_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$
 L_{stir} (Length of stirrups along X) = 1060.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 140000.00

$s = 300.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 15.00$
 From ((5.A5), TBDY), TBDY: $\alpha_c = 0.002$
 α_c = confinement factor = 1.00
 $y_1 = 0.00231479$
 $sh_1 = 0.008$
 $ft_1 = 666.66$
 $fy_1 = 555.55$
 $su_1 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $l_o / l_{ou,min} = l_b / l_d = 1.00$
 $su_1 = 0.4 * \alpha_{su1,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $\alpha_{su1,nominal} = 0.08$,
 For calculation of $\alpha_{su1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fs_1 = fs_1 / 1.2$, 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, ASCE 41-17.
 with $fs_1 = fs = 555.55$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.00231479$
 $sh_2 = 0.008$
 $ft_2 = 666.66$
 $fy_2 = 555.55$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $l_o / l_{ou,min} = l_b / l_{b,min} = 1.00$
 $su_2 = 0.4 * \alpha_{su2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $\alpha_{su2,nominal} = 0.08$,

For calculation of $es_{u2_nominal}$ 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, ASCE 41-17.

with $fs_2 = fs = 555.55$
with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$
 $sh_v = 0.008$
 $ft_v = 666.66$
 $fy_v = 555.55$
 $s_{uv} = 0.032$

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, ASCE 41-17.

with $f_{sv} = fs = 555.55$
with $Es_v = Es = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.79475296$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.37736471$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.7032706$

and confined core properties:

$b = 140.00$
 $d = 377.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 15.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 1.22571$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.58199105$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 1.08462$

Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)

--->

$v < v_{s,c}$ - RHS eq.(4.5) is not satisfied

--->

Case/Assumption Rejected.

--->

New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)

--->

$v < s_{y1}$ - LHS eq.(4.7) is not satisfied

--->

$v < v_{c,y1}$ - RHS eq.(4.6) is not satisfied

--->

$cu (4.11) = 0.87422556$
 $M_{Rc} (4.18) = 2.0582E+008$

--->

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 not satisfied
---->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 9.8367160E-006
Mu = MRc

```

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

```

u = 1.6866617E-005
Mu = 4.5595E+008

```

with full section properties:

```

b = 450.00
d = 407.00
d' = 43.00
v = 0.5682084
N = 1.5610E+006
fc = 15.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.0035
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.0035
we (5.4c) = 0.00
ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.00
The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization
of the rectangular sections confinement, which is expressed by (5.4d).
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)
"Theoretical Stress-Strain Model for Confined Concrete."
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
Aconf,max = 89600.00 is the confined core area at levels of member with hoops and
is calculated as the area of core enclosed by the center lines of the perimeter hoops.
Aconf,min = 0.00 is the confined core area at midway between the levels of hoops and
is calculated by reducing all the dimensions of the area Aconf,max by a length
equal to half the clear spacing between hoops.
AnoConf = 54733.333 is the unconfined core area which is equal to bi2/6 as defined at (A.2).
psh,min = Min(psh,x , psh,y) = 0.0019822
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) = 0.0019822
Lstir (Length of stirrups along Y) = 1060.00
Astir (stirrups area) = 78.53982
Asec (section area) = 140000.00

```

```

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.0019822
Lstir (Length of stirrups along X) = 1060.00
Astir (stirrups area) = 78.53982
Asec (section area) = 140000.00

```

```

s = 300.00
fywe = 555.55

```

```

fce = 15.00
From ((5A.5), TBDY), TBDY:  $c = 0.002$ 
 $c$  = 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
 $lo/lou,min = lb/ld = 1.00$ 
 $su_1 = 0.4 * esu_1,nominal ((5.5), TBDY) = 0.032$ 
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  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.
with  $fs_1 = fs = 555.55$ 
with  $Es_1 = Es = 200000.00$ 
 $y_2 = 0.00231479$ 
 $sh_2 = 0.008$ 
 $ft_2 = 666.66$ 
 $fy_2 = 555.55$ 
 $su_2 = 0.032$ 
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $lo/lou,min = lb/lb,min = 1.00$ 
 $su_2 = 0.4 * esu_2,nominal ((5.5), TBDY) = 0.032$ 
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.
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.
with  $fs_2 = fs = 555.55$ 
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  $y_v, sh_v, ft_v, fy_v$ , it is considered
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.
with  $fsv = fs = 555.55$ 
with  $Esv = Es = 200000.00$ 
 $1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.16771765$ 
 $2 = Asl,com / (b * d) * (fs_2 / fc) = 0.35322354$ 
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.31256471$ 
and confined core properties:
 $b = 390.00$ 
 $d = 377.00$ 
 $d' = 13.00$ 
 $f_{cc} (5A.2, TBDY) = 15.00$ 
 $cc (5A.5, TBDY) = 0.002$ 
 $c$  = confinement factor = 1.00
 $1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.20891986$ 
 $2 = Asl,com / (b * d) * (fs_2 / fc) = 0.4399979$ 
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.38935066$ 
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)

```

```

---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
'satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.5098538
MRc (4.17) = 4.5595E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N1, N2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.56860508
MRo (4.18) = 3.5813E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 1.6866617E-005
Mu = MRc

```

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 9.8367160E-006

Mu = 2.0582E+008

with full section properties:

```

b = 200.00
d = 407.00
d' = 43.00
v = 1.27847
N = 1.5610E+006
fc = 15.00
co (5A.5, TBDY) = 0.002
Final value of cu* = shear_factor * Max( cu, cc) = 0.0035
The Shear_factor is considered equal to 1 (pure moment strength)

```


From (5.4b), TBDY: $c_u = 0.0035$
 w_e (5.4c) = 0.00
 $a_s = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.00$
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.
 $A_{\text{conf,max}} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{\text{conf,min}} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max}}$ by a length equal to half the clear spacing between hoops.
 $A_{\text{noConf}} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.0019822$
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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$
 L_{stir} (Length of stirrups along Y) = 1060.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 140000.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$
 L_{stir} (Length of stirrups along X) = 1060.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 140000.00

$s = 300.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.002$
 c = confinement factor = 1.00

$y_1 = 0.00231479$
 $sh_1 = 0.008$
 $ft_1 = 666.66$
 $fy_1 = 555.55$
 $su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$su_1 = 0.4 * esu_{1,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$
 $sh_2 = 0.008$
 $ft_2 = 666.66$
 $fy_2 = 555.55$
 $su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 * esu_{2,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2 , sh_2 , ft_2 , fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2 , sh_2 , ft_2 , fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$
 $sh_v = 0.008$

```

ftv = 666.66
fyv = 555.55
suv = 0.032
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/ld = 1.00
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
    with fsv = fs = 555.55
    with Esv = Es = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.79475296
    2 = Asl,com/(b*d)*(fs2/fc) = 0.37736471
    v = Asl,mid/(b*d)*(fsv/fc) = 0.7032706
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
    c = confinement factor = 1.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
    2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
    v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008

```

$$M_{Ro} < 0.8 \cdot M_{Rc}$$

---->

$$u = c_u \text{ (unconfined full section)} = 9.8367160E-006$$

$$M_u = M_{Rc}$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of M_{u2}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 1.6866617E-005$$

$$M_u = 4.5595E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.5682084$$

$$N = 1.5610E+006$$

$$f_c = 15.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0035$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0035$$

$$w_e \text{ (5.4c)} = 0.00$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.0019822$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1060.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 140000.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1060.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 140000.00$$

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$f_{t1} = 666.66$$

$$f_{y1} = 555.55$$

```

su1 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fs1 = fs = 555.55
with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16771765
2 = Asl,com/(b*d)*(fs2/fc) = 0.35322354
v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)

```

```

---->
v < s,y1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is satisfied
---->
cu (4.10) = 0.5098538
MRc (4.17) = 4.5595E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.56860508
MRo (4.18) = 3.5813E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 1.6866617E-005
Mu = MRc

```

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 165623.448$

Calculation of Shear Strength at edge 1, $V_{r1} = 165623.448$

$V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = knl * V_{Co10}$

$V_{Co10} = 165623.448$

$knl = 1$ (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)

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$Mu = 1.4432E+008$

$Vu = 5.2893364E-006$

$d = 0.8 * h = 360.00$

$Nu = 1.5610E+006$

$Ag = 90000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 160.00$

$Av = 157079.633$

$f_y = 444.44$

$s = 300.00$
 $Vs1$ is multiplied by $Col1 = 0.00$
 $s/d = 1.875$
 $Vs2 = 55849.978$ is calculated for section flange, with:
 $d = 360.00$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 300.00$
 $Vs2$ is multiplied by $Col2 = 0.66666667$
 $s/d = 0.83333333$
 $Vf ((11-3)-(11.4), ACI 440) = 0.00$
 From (11-11), ACI 440: $Vs + Vf \leq 185244.312$
 $bw = 200.00$

Calculation of Shear Strength at edge 2, $Vr2 = 165623.448$
 $Vr2 = VCol ((10.3), ASCE 41-17) = knl * VCol0$
 $VCol0 = 165623.448$
 $knl = 1$ (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)
 $fc' = 15.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $Mu = 1.2049E+008$
 $Vu = 5.2893364E-006$
 $d = 0.8 * h = 360.00$
 $Nu = 1.5610E+006$
 $Ag = 90000.00$
 From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 55849.978$
 where:
 $Vs1 = 0.00$ is calculated for section web, with:
 $d = 160.00$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 300.00$
 $Vs1$ is multiplied by $Col1 = 0.00$
 $s/d = 1.875$
 $Vs2 = 55849.978$ is calculated for section flange, with:
 $d = 360.00$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 300.00$
 $Vs2$ is multiplied by $Col2 = 0.66666667$
 $s/d = 0.83333333$
 $Vf ((11-3)-(11.4), ACI 440) = 0.00$
 From (11-11), ACI 440: $Vs + Vf \leq 185244.312$
 $bw = 200.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
 At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1
 At local axis: 2
 Integration Section: (b)
 Section Type: rclcs

Constant Properties

Knowledge Factor, $= 1.00$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 15.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 450.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 450.00$

Min Width, $W_{min} = 200.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/l_d \geq 1$)

No FRP Wrapping

Stepwise Properties

Bending Moment, $M = 1.2511E+008$

Shear Force, $V_2 = -203511.132$

Shear Force, $V_3 = -0.05075246$

Axial Force, $F = -1.5625E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 1030.442$

-Compression: $A_{sc} = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{st,ten} = 829.3805$

-Compression: $A_{sc,com} = 1746.726$

-Middle: $A_{st,mid} = 1545.664$

Mean Diameter of Tension Reinforcement, $Db_L = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = u = 0.02445888$

$u = y + p = 0.02445888$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.02445888$ ((4.29), Biskinis Phd))

$M_y = 3.4090E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 6000.00

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 2.7875E+013$

factor = 0.70

$A_g = 140000.00$

$f_c' = 15.00$

$N = 1.5625E+006$

$E_c * I_g = 3.9822E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

Assuming neutral axis out of flange ($y > t/d$, compression zone NOT rectangular)

extended expressions (2.1)-(2.7) of Biskinis-Fardis (2009) are adopted with:

flange width, $b = 450.00$

web width, $b_w = 200.00$

flange thickness, $t = 200.00$

```

y = Min( y_ten, y_com)
y_ten = 1.0246803E-005
with fy = 444.44
d = 407.00
y = 0.46715567
A = 0.14973202
B = 0.07987948
with pt = 0.0019822
pc = 0.00953713
pv = 0.00843933
N = 1.5625E+006
b = 450.00
" = 0.10565111
y_comp = 6.6375136E-006
with fc = 15.00
Ec = 18203.022
y = 0.54906081
A = 0.04183593
B = 0.03668953
with Es = 200000.00
CONFIRMATION: y = 0.54906081 > t/d

```

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

- Calculation of p -

From table 10-8: $p = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
shear control ratio $V_y E / V_{col} E = 1.8353$

$d = 407.00$

$s = 100.00$

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.0019822$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 1060.00$, is the total Length of all stirrups parallel to loading (shear) direction

The term $2 * t_f / b_w * (f_{fe} / f_s)$ is implemented to account for FRP contribution

where $f = 2 * t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

$NUD = 1.5625E+006$

$A_g = 140000.00$

$f_{cE} = 15.00$

$f_{yE} = f_{yI} = 444.44$

$p_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.02250488$

$b = 450.00$

$d = 407.00$

$f_{cE} = 15.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 15

column C1, Floor 1

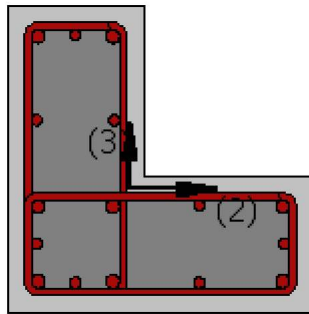
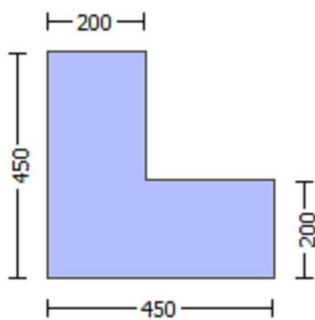
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rdcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 10.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 18203.022$

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, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 15.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

Max Height, $H_{max} = 450.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 450.00$

Min Width, $W_{min} = 200.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou,min} = l_b/l_d \geq 1$)
No FRP Wrapping

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -3.0515E+008$
Shear Force, $V_a = 0.05075246$
EDGE -B-
Bending Moment, $M_b = 1.2511E+008$
Shear Force, $V_b = -0.05075246$
BOTH EDGES
Axial Force, $F = -1.5625E+006$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 1030.442$
-Compression: $As_c = 3091.327$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 829.3805$
-Compression: $As_{c,com} = 1746.726$
-Middle: $As_{l,mid} = 1545.664$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = V_n = 148584.633$
 $V_n ((10.3), ASCE 41-17) = k_n * V_{CoI0} = 148584.633$
 $V_{CoI} = 148584.633$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.26586711$

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)
 $f'_c = 10.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 1.2511E+008$
 $V_u = 0.05075246$
 $d = 0.8 * h = 360.00$
 $N_u = 1.5625E+006$
 $A_g = 90000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 50265.482$
where:
 $V_{s1} = 50265.482$ is calculated for section web, with:
 $d = 360.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 300.00$
 V_{s1} is multiplied by $Col1 = 0.66666667$
 $s/d = 0.83333333$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 160.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 300.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.875$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
From (11-11), ACI 440: $V_s + V_f \leq 151251.347$
 $bw = 200.00$

$displacement_ductility_demand$ is calculated as δ / y

- Calculation of ϕ_y for END B -
for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 0.00650281$
 $y = (M_y * L_s / 3) / E_{eff} = 0.02445888$ ((4.29), Biskinis Phd))
 $M_y = 3.4090E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 6000.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 2.7875E+013$
 $factor = 0.70$
 $A_g = 140000.00$
 $f_c' = 15.00$
 $N = 1.5625E+006$
 $E_c * I_g = 3.9822E+013$

Calculation of Yielding Moment M_y

Calculation of ϕ_y and M_y according to Annex 7 -

Assuming neutral axis out of flange ($\phi_y > t/d$, compression zone NOT rectangular)
extended expressions (2.1)-(2.7) of Biskinis-Fardis (2009) are adopted with:
flange width, $b = 450.00$
web width, $b_w = 200.00$
flange thickness, $t = 200.00$

$y = \text{Min}(\phi_{y_ten}, \phi_{y_com})$
 $\phi_{y_ten} = 1.0246803E-005$
with $f_y = 444.44$
 $d = 407.00$
 $y = 0.46715567$
 $A = 0.14973202$
 $B = 0.07987948$
with $p_t = 0.00452842$
 $p_c = 0.00953713$
 $p_v = 0.00843933$
 $N = 1.5625E+006$
 $b = 450.00$
 $\phi_{y_com} = 0.10565111$
 $\phi_{y_comp} = 6.6375136E-006$
with $f_c = 15.00$
 $E_c = 18203.022$
 $y = 0.54906081$
 $A = 0.04183593$
 $B = 0.03668953$
with $E_s = 200000.00$
CONFIRMATION: $\phi_y = 0.54906081 > t/d$

Calculation of ratio I_b/I_d

Adequate Lap Length: $I_b/I_d \geq 1$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1
At local axis: 3
Integration Section: (b)

Calculation No. 16

column C1, Floor 1

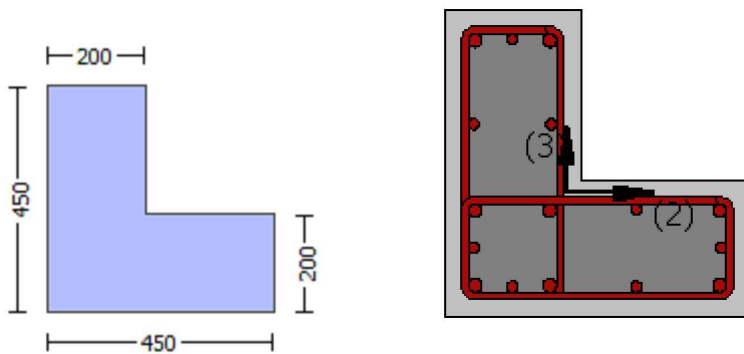
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ_r)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rdcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 15.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height, $H_{max} = 450.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 450.00$

Min Width, $W_{min} = 200.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou, min} \geq 1$)

No FRP Wrapping

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 2.2161626E-006$

EDGE -B-

Shear Force, $V_b = -2.2161626E-006$

BOTH EDGES

Axial Force, $F = -1.5610E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 716.2831$

-Compression: $As_c = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 829.3805$

-Compression: $As_{c,com} = 1746.726$

-Middle: $As_{mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.8353$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 303967.895$

with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 4.5595E+008$

$\mu_{1+} = 4.5595E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{1-} = 2.0582E+008$, 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 4.5595E+008$

$\mu_{2+} = 4.5595E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 2.0582E+008$, 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 according to 4.1, Biskinis/Fardis 2013:

$\mu = 1.6866617E-005$

$M_u = 4.5595E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.5682084$

$N = 1.5610E+006$

$f_c = 15.00$

$\phi = (5A.5, \text{TB DY}) = 0.002$

Final value of ϕ : $\phi^* = \text{shear_factor} * \text{Max}(\phi, \phi_c) = 0.0035$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TB DY: $\phi = 0.0035$

$\phi_{we} = 0.00$

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.00$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.

Aconf,min = 0.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 54733.333 is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.0019822

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) = 0.0019822

Lstir (Length of stirrups along Y) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.0019822

Lstir (Length of stirrups along X) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

s = 300.00

fywe = 555.55

fce = 15.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/lb,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

```

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16771765
2 = Asl,com/(b*d)*(fs2/fc) = 0.35322354
v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.5098538
MRc (4.17) = 4.5595E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
--->
v* < v*s,c - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
--->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
--->
*cu (4.11) = 0.56860508
MRo (4.18) = 3.5813E+008
MRo < 0.8*MRc
--->
u = cu (unconfined full section) = 1.6866617E-005
Mu = MRc

```

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Mu1-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 9.8367160E-006$$

$$\mu_u = 2.0582E+008$$

with full section properties:

$$b = 200.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 1.27847$$

$$N = 1.5610E+006$$

$$f_c = 15.00$$

$$cc(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, cc) = 0.0035$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.0035$$

$$w_e(5.4c) = 0.00$$

$$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.0019822$$

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)

$$p_{sh,x}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1060.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 140000.00$$

$$p_{sh,y}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1060.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 140000.00$$

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

$$l_o/l_{o,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_1_{nominal}((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_1_{nominal} = 0.08,$$

For calculation of $esu_1_{nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = f_s/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.


```

with fs1 = fs = 555.55
with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/d = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.79475296
2 = Asl,com/(b*d)*(fs2/fc) = 0.37736471
v = Asl,mid/(b*d)*(fsv/fc) = 0.7032706
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is not satisfied
--->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made

```

- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu

--->

Subcase: Rupture of tension steel

--->

$v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

$v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

$v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

--->

$v^* < v^*_{c,y1}$ - RHS eq.(4.6) is not satisfied

--->

$*cu$ (4.11) = 1.00

MRO (4.18) = 1.2754E+008

MRO < 0.8*MRC

--->

u = cu (unconfined full section) = 9.8367160E-006

Mu = MRC

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.6866617E-005

Mu = 4.5595E+008

with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.5682084

N = 1.5610E+006

fc = 15.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0035$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.0035

we (5.4c) = 0.00

ase = $\text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max = 89600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

Aconf,min = 0.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 54733.333 is the unconfined core area which is equal to bi2/6 as defined at (A.2).

psh,min = Min(psh,x, psh,y) = 0.0019822

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)

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.0019822$$

$$Lstir \text{ (Length of stirrups along Y)} = 1060.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 140000.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.0019822$$

$$Lstir \text{ (Length of stirrups along X)} = 1060.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 140000.00$$

$$s = 300.00$$

$$fywe = 555.55$$

$$fce = 15.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

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

$$lo/lou,min = lb/d = 1.00$$

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_nominal = 0.08,$$

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

$$y1, sh1,ft1,fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs1 = fs = 555.55$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00231479$$

$$sh2 = 0.008$$

$$ft2 = 666.66$$

$$fy2 = 555.55$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 1.00$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_nominal = 0.08,$$

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

$$y2, sh2,ft2,fy2, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs2 = fs = 555.55$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00231479$$

$$shv = 0.008$$

$$ftv = 666.66$$

$$fyv = 555.55$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/d = 1.00$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esuv_nominal = 0.08,$$

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

$$y1, sh1,ft1,fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fsv = fs = 555.55$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.16771765$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.35322354$$

```

v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < s,y1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.5098538
MRc (4.17) = 4.5595E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
--->
v* < v*s,c - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
--->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
--->
*cu (4.11) = 0.56860508
MRo (4.18) = 3.5813E+008
MRo < 0.8*MRc
--->
u = cu (unconfined full section) = 1.6866617E-005
Mu = MRc

```

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 9.8367160E-006
Mu = 2.0582E+008

with full section properties:

b = 200.00
d = 407.00
d' = 43.00
v = 1.27847
N = 1.5610E+006

fc = 15.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.0035

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.0035

we (5.4c) = 0.00

ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.00

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max = 89600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

Aconf,min = 0.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 54733.333 is the unconfined core area which is equal to bi2/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.0019822

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) = 0.0019822

Lstir (Length of stirrups along Y) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.0019822

Lstir (Length of stirrups along X) = 1060.00

Astir (stirrups area) = 78.53982

Asec (section area) = 140000.00

s = 300.00

fywe = 555.55

fce = 15.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

```

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/d = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.79475296
2 = Asl,com/(b*d)*(fs2/fc) = 0.37736471
v = Asl,mid/(b*d)*(fsv/fc) = 0.7032706
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < s,y1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is not satisfied
--->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied

```

```

---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 9.8367160E-006
Mu = MRc
-----

Calculation of ratio lb/lc
-----
Adequate Lap Length: lb/lc >= 1
-----
-----
-----
Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 165623.448
-----
Calculation of Shear Strength at edge 1, Vr1 = 165623.448
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VColO
VColO = 165623.448
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' = 15.00, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 1.4825E+008
Vu = 2.2161626E-006
d = 0.8*h = 360.00
Nu = 1.5610E+006
Ag = 90000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 55849.978
where:
Vs1 = 55849.978 is calculated for section web, with:
d = 360.00
Av = 157079.633
fy = 444.44
s = 300.00
Vs1 is multiplied by Col1 = 0.66666667
s/d = 0.83333333
Vs2 = 0.00 is calculated for section flange, with:
d = 160.00
Av = 157079.633
fy = 444.44
s = 300.00
Vs2 is multiplied by Col2 = 0.00
s/d = 1.875
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 185244.312
bw = 200.00
-----
Calculation of Shear Strength at edge 2, Vr2 = 165623.448
Vr2 = VCol ((10.3), ASCE 41-17) = knl*VColO

```

VColO = 165623.448

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' = 15.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 1.2485E+008

Vu = 2.2161626E+006

d = 0.8*h = 360.00

Nu = 1.5610E+006

Ag = 90000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 55849.978

where:

Vs1 = 55849.978 is calculated for section web, with:

d = 360.00

Av = 157079.633

fy = 444.44

s = 300.00

Vs1 is multiplied by Col1 = 0.66666667

s/d = 0.83333333

Vs2 = 0.00 is calculated for section flange, with:

d = 160.00

Av = 157079.633

fy = 444.44

s = 300.00

Vs2 is multiplied by Col2 = 0.00

s/d = 1.875

Vf ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: Vs + Vf <= 185244.312

bw = 200.00

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rccls

Constant Properties

Knowledge Factor, = 1.00

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, fc = fcm = 15.00

Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44

Concrete Elasticity, Ec = 18203.022

Steel Elasticity, Es = 200000.00

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, fs = 1.25*fsm = 555.55

#####

Max Height, Hmax = 450.00

Min Height, Hmin = 200.00

Max Width, Wmax = 450.00

Min Width, Wmin = 200.00

Cover Thickness, c = 25.00

Mean Confinement Factor overall section = 1.00

Element Length, L = 3000.00

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou}, \min \geq 1$)

No FRP Wrapping

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = -5.2893364E-006$

EDGE -B-

Shear Force, $V_b = 5.2893364E-006$

BOTH EDGES

Axial Force, $F = -1.5610E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 716.2831$

-Compression: $As_c = 3091.327$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1746.726$

-Compression: $As_{l,com} = 829.3805$

-Middle: $As_{l,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.8353$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 303967.895$

with

$M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 4.5595E+008$

$\mu_{u1+} = 2.0582E+008$, 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

$\mu_{u1-} = 4.5595E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 4.5595E+008$

$\mu_{u2+} = 2.0582E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{u2-} = 4.5595E+008$, 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_{u1+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$\mu_u = 9.8367160E-006$

$\mu_u = 2.0582E+008$

with full section properties:

$b = 200.00$

$d = 407.00$

$d' = 43.00$

$v = 1.27847$

$N = 1.5610E+006$

$f_c = 15.00$

ϕ_o (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \max(\phi_u, \phi_o) = 0.0035$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.0035$

ϕ_{ue} (5.4c) = 0.00

$\phi_{ase} = \max(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.00$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.0019822$

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)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

L_{stir} (Length of stirrups along Y) = 1060.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$

L_{stir} (Length of stirrups along X) = 1060.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

$s = 300.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.002$

c = confinement factor = 1.00

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/ld = 1.00$

$su_1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/lb,min = 1.00$

$su_2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

```

and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lo,min = lb/ld = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.79475296
2 = Asl,com/(b*d)*(fs2/fc) = 0.37736471
v = Asl,mid/(b*d)*(fsv/fc) = 0.7032706
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.22571
2 = Asl,com/(b*d)*(fs2/fc) = 0.58199105
v = Asl,mid/(b*d)*(fsv/fc) = 1.08462
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
---->
v < vs,c - RHS eq.(4.5) is not satisfied
---->
Case/Assumption Rejected.
---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
---->
v < sy1 - LHS eq.(4.7) is not satisfied
---->
v < vc,y1 - RHS eq.(4.6) is not satisfied
---->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*cy2 - LHS eq.(4.6) is not satisfied
---->
v* < v*cy1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 9.8367160E-006
Mu = MRc

```

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:

$$\mu_u = 1.6866617E-005$$

$$\mu_u = 4.5595E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$\nu = 0.5682084$$

$$N = 1.5610E+006$$

$$f_c = 15.00$$

$$\omega (5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \omega) = 0.0035$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \mu_u = 0.0035$$

$$\text{we (5.4c) } = 0.00$$

$$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i d_i / 6$ as defined at (A.2).

$$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.0019822$$

Expression ((5.4d), TB DY) for $\mu_{psh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\mu_{psh,x} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1060.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 140000.00$$

$$\mu_{psh,y} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

$$L_{stir} (\text{Length of stirrups along X}) = 1060.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 140000.00$$

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \omega_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

```

lo/lou,min = lb/d = 1.00
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.
with fs1 = fs = 555.55
with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/d = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16771765
2 = Asl,com/(b*d)*(fs2/fc) = 0.35322354
v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied

```

```

---->
cu (4.10) = 0.5098538
MRc (4.17) = 4.5595E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*s,y2 - LHS eq.(4.5) is not satisfied
---->
v* < v*s,c - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.56860508
MRo (4.18) = 3.5813E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 1.6866617E-005
Mu = MRc
-----

Calculation of ratio lb/d
-----
Adequate Lap Length: lb/d >= 1
-----
-----

Calculation of Mu2+
-----
-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 9.8367160E-006
Mu = 2.0582E+008
-----

with full section properties:
b = 200.00
d = 407.00
d' = 43.00
v = 1.27847
N = 1.5610E+006
fc = 15.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.0035
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.0035
we (5.4c) = 0.00
ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.00
The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization
of the rectangular sections confinement, which is expressed by (5.4d).
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)
"Theoretical Stress-Strain Model for Confined Concrete."
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
Aconf,max = 89600.00 is the confined core area at levels of member with hoops and
is calculated as the area of core enclosed by the center lines of the perimeter hoops.
Aconf,min = 0.00 is the confined core area at midway between the levels of hoops and

```

is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh_{min} = \min(psh_x, psh_y) = 0.0019822$

Expression ((5.4d), TBDY) for psh_{min} has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

 $psh_x \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.0019822$

L_{stir} (Length of stirrups along Y) = 1060.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

 $psh_y \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.0019822$

L_{stir} (Length of stirrups along X) = 1060.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 140000.00

 $s = 300.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.002$

c = confinement factor = 1.00

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$su_1 = 0.4 \cdot esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = f_s/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = f_s = 555.55$

with $Es_1 = E_s = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 \cdot esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = f_s/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_2 = f_s = 555.55$

with $Es_2 = E_s = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$suv = 0.032$

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

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$suv = 0.4 \cdot esuv_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $fsy_v = f_s/1.2$, from table 5.1, TBDY

For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

```

characteristic value  $f_{sv} = f_{sv}/1.2$ , 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, ASCE 41-17.
with  $f_{sv} = f_s = 555.55$ 
with  $E_{sv} = E_s = 200000.00$ 
1 =  $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.79475296$ 
2 =  $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.37736471$ 
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.7032706$ 
and confined core properties:
b = 140.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 =  $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 1.22571$ 
2 =  $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.58199105$ 
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 1.08462$ 
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
 $v < v_{s,c}$  - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
 $v < s_{y1}$  - LHS eq.(4.7) is not satisfied
--->
 $v < v_{c,y1}$  - RHS eq.(4.6) is not satisfied
--->
cu (4.11) = 0.87422556
MRc (4.18) = 2.0582E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core:  $b_o, d_o, d'_o$ 
-  $N_1, N_2, v$  normalised to  $b_o \cdot d_o$ , instead of  $b \cdot d$ 
- parameters of confined concrete, fcc, cc, used in lieu of  $f_c, e_{cu}$ 
--->
Subcase: Rupture of tension steel
--->
 $v^* < v^*_{s,y2}$  - LHS eq.(4.5) is not satisfied
--->
 $v^* < v^*_{s,c}$  - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->
New Subcase: Failure of compression zone
--->
 $v^* < v^*_{c,y2}$  - LHS eq.(4.6) is not satisfied
--->
 $v^* < v^*_{c,y1}$  - RHS eq.(4.6) is not satisfied
--->
*cu (4.11) = 1.00
MRo (4.18) = 1.2754E+008
MRo < 0.8*MRc
--->
u = cu (unconfined full section) = 9.8367160E-006
Mu = MRc
-----

```

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Mu2-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.6866617E-005$$

$$\mu_u = 4.5595E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.5682084$$

$$N = 1.5610E+006$$

$$f_c = 15.00$$

$$c_o(5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, c_o) = 0.0035$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \mu_u = 0.0035$$

$$\mu_{ue} (5.4c) = 0.00$$

$$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 89600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 54733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$\mu_{sh,min} = \text{Min}(\mu_{sh,x}, \mu_{sh,y}) = 0.0019822$$

Expression ((5.4d), TB DY) for $\mu_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\mu_{sh,x} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1060.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 140000.00$$

$$\mu_{sh,y} ((5.4d), \text{TB DY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.0019822$$

$$L_{stir} (\text{Length of stirrups along X}) = 1060.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 140000.00$$

$$s = 300.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From ((5.A5), TB DY), TB DY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with

$$\text{Shear_factor} = 1.00$$

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_1_{nominal} ((5.5), \text{TB DY}) = 0.032$$

$$\text{From table 5A.1, TB DY: } esu_1_{nominal} = 0.08,$$

For calculation of $esu_1_{nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TB DY.

$$y_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (l_b/l_d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs_1 = fs = 555.55$$

```

with Es1 = Es = 200000.00
y2 = 0.00231479
sh2 = 0.008
ft2 = 666.66
fy2 = 555.55
su2 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = fs = 555.55
with Es2 = Es = 200000.00
yv = 0.00231479
shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16771765
2 = Asl,com/(b*d)*(fs2/fc) = 0.35322354
v = Asl,mid/(b*d)*(fsv/fc) = 0.31256471
and confined core properties:
b = 390.00
d = 377.00
d' = 13.00
fcc (5A.2, TBDY) = 15.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.20891986
2 = Asl,com/(b*d)*(fs2/fc) = 0.4399979
v = Asl,mid/(b*d)*(fsv/fc) = 0.38935066
Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)
--->
v < vs,c - RHS eq.(4.5) is not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < sy1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.5098538
MRc (4.17) = 4.5595E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o

```

- N_1, N_2 v normalised to $b_o \cdot d_o$, instead of $b \cdot d$
- parameters of confined concrete, f_{cc}, ϵ_{cc} , used in lieu of f_c, ϵ_{cu}

--->

Subcase: Rupture of tension steel

--->

$v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

$v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

$v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

--->

$v^* < v^*_{c,y1}$ - RHS eq.(4.6) is not satisfied

--->

$\epsilon_{cu} (4.11) = 0.56860508$

$M_{Ro} (4.18) = 3.5813E+008$

$M_{Ro} < 0.8 \cdot M_{Rc}$

--->

$\mu = \epsilon_{cu}$ (unconfined full section) = $1.6866617E-005$

$\mu_u = M_{Rc}$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 165623.448$

Calculation of Shear Strength at edge 1, $V_{r1} = 165623.448$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_n l^* V_{Col0}$

$V_{Col0} = 165623.448$

$k_n l = 1$ (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).

$\gamma = 1$ (normal-weight concrete)

$f'_c = 15.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/V_d = 4.00$

$\mu_u = 1.4432E+008$

$V_u = 5.2893364E-006$

$d = 0.8 \cdot h = 360.00$

$N_u = 1.5610E+006$

$A_g = 90000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 1.875$

$V_{s2} = 55849.978$ is calculated for section flange, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 300.00$

V_{s2} is multiplied by $Col2 = 0.66666667$

$s/d = 0.83333333$

$V_f ((11-3)-(11.4), ACI 440) = 0.00$

From (11-11), ACI 440: $V_s + V_f \leq 185244.312$
 $bw = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 165623.448$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 165623.448$
 $knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)
 $f'_c = 15.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 1.2049E+008$
 $V_u = 5.2893364E-006$
 $d = 0.8 * h = 360.00$
 $N_u = 1.5610E+006$
 $A_g = 90000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 55849.978$
where:
 $V_{s1} = 0.00$ is calculated for section web, with:
 $d = 160.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 300.00$
 V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 1.875$
 $V_{s2} = 55849.978$ is calculated for section flange, with:
 $d = 360.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 300.00$
 V_{s2} is multiplied by $Col2 = 0.66666667$
 $s/d = 0.83333333$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
From (11-11), ACI 440: $V_s + V_f \leq 185244.312$
 $bw = 200.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1
At local axis: 3
Integration Section: (b)
Section Type: rclcs

Constant Properties

Knowledge Factor, $= 1.00$
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 15.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 18203.022$
Steel Elasticity, $E_s = 200000.00$
Max Height, $H_{max} = 450.00$
Min Height, $H_{min} = 200.00$
Max Width, $W_{max} = 450.00$
Min Width, $W_{min} = 200.00$
Cover Thickness, $c = 25.00$

Element Length, L = 3000.00
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_b/l_d \geq 1$)
No FRP Wrapping

Stepwise Properties

Bending Moment, M = 1.6143E+008
Shear Force, V2 = -203511.132
Shear Force, V3 = -0.05075246
Axial Force, F = -1.5625E+006
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Asl,t = 1030.442
-Compression: Asl,c = 3091.327
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 1746.726
-Compression: Asl,com = 829.3805
-Middle: Asl,mid = 1545.664
Mean Diameter of Tension Reinforcement, DbL = 17.71429

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{R} = u = 0.00139908$
 $u = y + p = 0.00139908$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00139908$ ((4.29), Biskinis Phd))
 $M_y = 1.4750E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 793.2009
From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 2.7875E+013$
factor = 0.70
 $A_g = 140000.00$
 $f_c' = 15.00$
 $N = 1.5625E+006$
 $E_c * I_g = 3.9822E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 1.4509707E-005$
with $f_y = 444.44$
 $d = 407.00$
 $y = 0.62370357$
 $A = 0.09382593$
 $B = 0.07622229$
with $p_t = 0.0019822$
 $p_c = 0.01018895$
 $p_v = 0.0189885$
 $N = 1.5625E+006$
 $b = 200.00$
 $\alpha = 0.10565111$
 $y_{comp} = 3.5712582E-006$
with $f_c = 15.00$
 $E_c = 18203.022$
 $y = 1.02048$

A = -0.01407015
B = 0.03303234
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 not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$
shear control ratio $V_yE/V_{Col0E} = 1.8353$

$d = 407.00$

$s = 100.00$

$t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.0019822$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 1060.00$, is the total Length of all stirrups parallel to loading (shear) direction

The term $2*t_f/b_w*(f_{fe}/f_s)$ is implemented to account for FRP contribution

where $f = 2*t_f/b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe}/f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

$N_{UD} = 1.5625E+006$

$A_g = 140000.00$

$f_{cE} = 15.00$

$f_{ytE} = f_{ylE} = 444.44$

$p_l = \text{Area_Tot_Long_Rein}/(b*d) = 0.05063599$

$b = 200.00$

$d = 407.00$

$f_{cE} = 15.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)