

Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

column C1, Floor 1

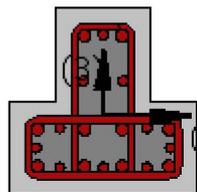
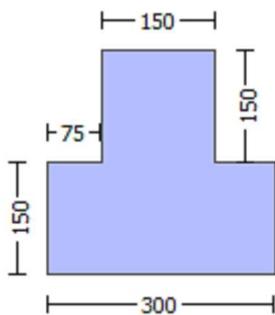
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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, $f_c = f_{c_lower_bound} = 16.00$

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

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

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

#####

Max Height, $H_{max} = 300.00$

Min Height, $H_{min} = 150.00$

Max Width, $W_{max} = 300.00$

Min Width, $W_{min} = 150.00$

Eccentricity, $Ecc = 75.00$

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, $M_a = -2.1593E+008$

Shear Force, $V_a = -33296.807$

EDGE -B-

Bending Moment, $M_b = -6.6728E+006$

Shear Force, $V_b = 33296.807$

BOTH EDGES

Axial Force, $F = -998863.21$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 2375.044$

-Compression: $As_c = 2777.168$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1231.504$

-Compression: $As_{c,com} = 1231.504$

-Middle: $As_{mid} = 2689.203$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.60$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 109333.59$

V_n ((10.3), ASCE 41-17) = $k_n l V_{CoI} = 128627.753$

$V_{CoI} = 128627.753$

$k_n l = 1.00$

displacement_ductility_demand = 1.03669

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

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

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

$M/Vd = 4.00$

$M_u = 2.1593E+008$

$V_u = 33296.807$

$d = 0.8 \cdot h = 240.00$

$N_u = 998863.21$

$A_g = 45000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 66138.793$

where:

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

$d = 120.00$

Av = 157079.633

fy = 400.00

s = 190.00

Vs1 is multiplied by Col1 = 0.00

s/d = 1.58333

Vs2 = 66138.793 is calculated for section flange, with:

d = 240.00

Av = 157079.633

fy = 400.00

s = 190.00

Vs2 is multiplied by Col2 = 0.83333333

s/d = 0.79166667

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

From (11-11), ACI 440: Vs + Vf <= 95659.751

bw = 150.00

displacement_ductility_demand is calculated as ϕ / y

- Calculation of ϕ / y for END A -

for rotation axis 3 and integ. section (a)

From analysis, chord rotation = 0.0409503

$y = (My * Ls / 3) / Eleff = 0.03950098$ ((4.29), Biskinis Phd))

My = 1.1034E+008

Ls = M/V (with Ls > 0.1*L and Ls < 2*L) = 6000.00

From table 10.5, ASCE 41_17: Eleff = factor * Ec * Ig = 5.5865E+012

factor = 0.70

Ag = 67500.00

fc' = 20.00

N = 998863.21

Ec * Ig = 7.9807E+012

Calculation of Yielding Moment My

Calculation of ϕ / y and My according to Annex 7 -

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

y_ten = 2.2096501E-005

with fy = 444.44

d = 257.00

y = 0.60868498

A = 0.19195011

B = 0.1363059

with pt = 0.03194564

pc = 0.03194564

pv = 0.06975884

N = 998863.21

b = 150.00

" = 0.16731518

y_comp = 8.4828072E-006

with fc = 20.00

Ec = 21019.039

y = 0.78562795

A = 0.05800829

B = 0.0780059

with Es = 200000.00

Calculation of ratio lb/d

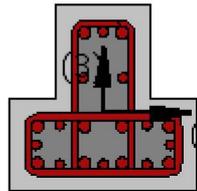
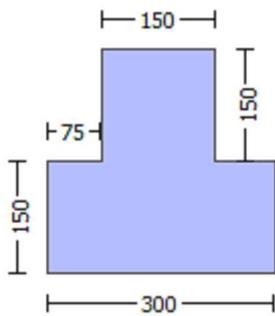
Adequate Lap Length: lb/d >= 1

End Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 2
Integration Section: (a)

Calculation No. 2

column C1, Floor 1
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)
Analysis: Uniform +X
Check: Chord rotation capacity (θ)
Edge: Start
Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At Shear local axis: 3
(Bending local axis: 2)
Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height, $H_{max} = 300.00$

Min Height, $H_{min} = 150.00$

Max Width, $W_{max} = 300.00$

Min Width, $W_{min} = 150.00$

Eccentricity, $E_{cc} = 75.00$

Cover Thickness, $c = 25.00$

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

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = -1.1623543E-006$
EDGE -B-
Shear Force, $V_b = 1.1623543E-006$
BOTH EDGES
Axial Force, $F = -1.0007E+006$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 5152.212$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten} = 2261.947$
-Compression: $A_{st,com} = 829.3805$
-Middle: $A_{st,mid} = 2060.885$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.14818$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 160672.713$
with
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.4101E+008$
 $Mu_{1+} = 1.4763E+008$, 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
 $Mu_{1-} = 2.4101E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.4101E+008$
 $Mu_{2+} = 1.4763E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination
 $Mu_{2-} = 2.4101E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 1.6767311E-005$
 $Mu = 1.4763E+008$

with full section properties:

$b = 150.00$
 $d = 257.00$
 $d' = 43.00$
 $v = 1.29793$
 $N = 1.0007E+006$
 $f_c = 20.00$
 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_w (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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00404182$$

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)

$$psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

L_{stir} (Length of stirrups along Y) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

$$psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

L_{stir} (Length of stirrups along X) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

c = confinement factor = 1.00

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

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

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

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

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

with $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

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

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

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

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

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

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

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

$$fy_v = 555.55$$

$suv = 0.032$
 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 $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 1.62986$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.59761649$
 $v = Asl,mid/(b*d)*(fsv/fc) = 1.48499$
 and confined core properties:
 $b = 90.00$
 $d = 227.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 3.07544$
 $2 = Asl,com/(b*d)*(fs2/fc) = 1.12766$
 $v = Asl,mid/(b*d)*(fsv/fc) = 2.80207$
 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
 --->
 $cu (4.11) = 0.81221594$
 $MRC (4.18) = 1.4763E+008$
 --->
 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
 --->
 $*cu (4.11) = 0.91366546$
 $MRO (4.18) = 8.4535E+007$
 $MRO < 0.8*MRC$
 --->

$u = cu$ (unconfined full section) = $1.6767311E-005$
 $Mu = MRc$

Calculation of ratio lb/ld

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

Calculation of $Mu1$

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

$u = 1.8792920E-005$
 $Mu = 2.4101E+008$

with full section properties:

$b = 300.00$
 $d = 257.00$
 $d' = 43.00$
 $v = 0.64896668$
 $N = 1.0007E+006$

$fc = 20.00$
 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.
 $Aconf,max = 35100.00$ is the 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.
 $AnoConf = 16650.00$ is the unconfined core area which is equal to $bi^2/6$ as defined at (A.2).
 $psh,min = Min(psh,x, psh,y) = 0.00404182$
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) = $Lstir * Astir / (Asec * s) = 0.00404182$
 $Lstir$ (Length of stirrups along Y) = 660.00
 $Astir$ (stirrups area) = 78.53982
 $Asec$ (section area) = 67500.00

psh,y ((5.4d), TBDY) = $Lstir * Astir / (Asec * s) = 0.00404182$
 $Lstir$ (Length of stirrups along X) = 660.00
 $Astir$ (stirrups area) = 78.53982
 $Asec$ (section area) = 67500.00

$s = 190.00$
 $fywe = 555.55$
 $fce = 20.00$
From ((5.A5), TBDY), TBDY: $cc = 0.002$
 $c =$ confinement factor = 1.00
 $y1 = 0.00231479$
 $sh1 = 0.008$
 $ft1 = 666.66$
 $fy1 = 555.55$
 $su1 = 0.032$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

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

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

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

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, 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) = 0.29880825

2 = Asl,com/(b*d)*(fs2/fc) = 0.81493158

v = Asl,mid/(b*d)*(fsv/fc) = 0.74249322

and confined core properties:

b = 240.00

d = 227.00

d' = 13.00

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.4228729

2 = Asl,com/(b*d)*(fs2/fc) = 1.15329

v = Asl,mid/(b*d)*(fsv/fc) = 1.05078

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

--->
c_u (4.10) = 0.45266836
MR_c (4.17) = 2.7366E+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_{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) = 0.46882405
MR_o (4.18) = 2.4101E+008

--->
u = c_u (4.2) = 1.8792920E-005
M_u = MR_o

Calculation of ratio l_b/l_d

Adequate Lap Length: l_b/l_d >= 1

Calculation of Mu₂₊

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.6767311E-005

M_u = 1.4763E+008

with full section properties:

b = 150.00
d = 257.00
d' = 43.00
v = 1.29793
N = 1.0007E+006

f_c = 20.00
c_o (5A.5, TBDY) = 0.002
Final value of c_u: c_u* = shear_factor * Max(c_u, c_{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} = 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} = 35100.00 is the 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 = 16650.00 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) = 0.00404182

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) = 0.00404182

Lstir (Length of stirrups along Y) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00404182

Lstir (Length of stirrups along X) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

s = 190.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

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

lo/lou,min = lb/d = 1.00

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

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

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

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, 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 $\text{Min}(1, 1.25*(lb/d)^{2/3})$, 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 $e_{suv_nominal}$ and y_v , sh_v, ft_v, fy_v , it is considered characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

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

with $f_{sv} = f_s = 555.55$

with $E_{sv} = E_s = 200000.00$

1 = $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 1.62986$

2 = $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.59761649$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 1.48499$

and confined core properties:

$b = 90.00$

$d = 227.00$

$d' = 13.00$

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

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 3.07544$

2 = $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 1.12766$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 2.80207$

Case/Assumption: Unconfined full section - Steel rupture

' does not satisfy Eq. (4.3)

--->

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

--->

Case/Assumption Rejected.

--->

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

' satisfies Eq. (4.4)

--->

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

--->

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

--->

c_u (4.11) = 0.81221594

M_{Rc} (4.18) = 1.4763E+008

--->

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

In expressions below, the following modifications have been made

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

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

- f_{cc} , cc , used in lieu of f_c , e_{cu}

--->

Subcase: Rupture of tension steel

--->

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

--->

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

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

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

--->

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

--->

$*c_u$ (4.11) = 0.91366546

M_{Ro} (4.18) = 8.4535E+007

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

--->

$u = c_u$ (unconfined full section) = 1.6767311E-005

$M_u = M_{Rc}$

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:

$$\mu = 1.8792920E-005$$

$$Mu = 2.4101E+008$$

with full section properties:

$$b = 300.00$$

$$d = 257.00$$

$$d' = 43.00$$

$$v = 0.64896668$$

$$N = 1.0007E+006$$

$$f_c = 20.00$$

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

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

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 660.00$$

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

$$A_{sec} \text{ (section area)} = 67500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along X)} = 660.00$$

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

$$A_{sec} \text{ (section area)} = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

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

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

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

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

with $f_{s1} = f_s = 555.55$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.00231479$
 $sh_2 = 0.008$
 $ft_2 = 666.66$
 $fy_2 = 555.55$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 1.00$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, 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
 $l_o/l_{o,min} = l_b/l_d = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsy_v = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsy_v = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $f_{sv} = f_s = 555.55$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.29880825$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.81493158$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.74249322$
 and confined core properties:
 $b = 240.00$
 $d = 227.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.4228729$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 1.15329$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 1.05078$
 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
 --->
 $cu (4.10) = 0.45266836$
 $MRC (4.17) = 2.7366E+008$
 --->
 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) = 0.46882405

MRO (4.18) = 2.4101E+008

u = cu (4.2) = 1.8792920E-005

Mu = MRO

 Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

 Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 139936.984

 Calculation of Shear Strength at edge 1, Vr1 = 139936.984

Vr1 = VCol ((10.3), ASCE 41-17) = knl*VCol0

VCol0 = 139936.984

knl = 1 (zero step-static loading)

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

 = 1 (normal-weight concrete)

fc' = 20.00, but $fc^{0.5} <= 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 934188.794

Vu = 1.1623543E-006

d = 0.8*h = 240.00

Nu = 1.0007E+006

Ag = 45000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 73486.813

where:

Vs1 = 73486.813 is calculated for section web, with:

d = 240.00

Av = 157079.633

fy = 444.44

s = 190.00

Vs1 is multiplied by Col1 = 0.83333333

s/d = 0.79166667

Vs2 = 0.00 is calculated for section flange, with:

d = 120.00

Av = 157079.633

fy = 444.44

s = 190.00

Vs2 is multiplied by Col2 = 0.00

s/d = 1.58333

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

From (11-11), ACI 440: $V_s + V_f \leq 106950.853$
 $bw = 150.00$

Calculation of Shear Strength at edge 2, $V_r2 = 139936.984$
 $V_r2 = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 139936.984$
 $knl = 1$ (zero step-static loading)

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

= 1 (normal-weight concrete)
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 760.756$
 $V_u = 1.1623543E+006$
 $d = 0.8 * h = 240.00$
 $N_u = 1.0007E+006$
 $A_g = 45000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$
where:
 $V_{s1} = 73486.813$ is calculated for section web, with:
 $d = 240.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 190.00$
 V_{s1} is multiplied by $Col1 = 0.83333333$
 $s/d = 0.79166667$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 120.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 190.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.58333$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
From (11-11), ACI 440: $V_s + V_f \leq 106950.853$
 $bw = 150.00$

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rctcs

Constant Properties

Knowledge Factor, $\phi = 0.85$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Secondary Member: Concrete Strength, $fc = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

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

Max Height, $H_{max} = 300.00$

Min Height, Hmin = 150.00
Max Width, Wmax = 300.00
Min Width, Wmin = 150.00
Eccentricity, Ecc = 75.00
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: 2
EDGE -A-
Shear Force, Va = -5.7446150E-009
EDGE -B-
Shear Force, Vb = 5.7446150E-009
BOTH EDGES
Axial Force, F = -1.0007E+006
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 5152.212
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 1231.504
-Compression: Asl,com = 1231.504
-Middle: Asl,mid = 2689.203

Calculation of Shear Capacity ratio, $V_e/V_r = 0.62533189$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 129060.47$
with
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.9359E+008$
 $Mu_{1+} = 1.9359E+008$, 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
 $Mu_{1-} = 1.9359E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.9359E+008$
 $Mu_{2+} = 1.9359E+008$, 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
 $Mu_{2-} = 1.9359E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 1.9679130E-005$
 $M_u = 1.9359E+008$

with full section properties:

b = 150.00
d = 257.00
d' = 43.00
v = 1.29793
N = 1.0007E+006
fc = 20.00

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

$$\text{Final value of } c_u = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0035$$

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$$

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)

$$p_{sh,x} \text{ (5.4d), TBDY} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 660.00$$

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

$$A_{sec} \text{ (section area)} = 67500.00$$

$$p_{sh,y} \text{ (5.4d), TBDY} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along X)} = 660.00$$

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

$$A_{sec} \text{ (section area)} = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

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

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

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

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

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

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

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

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

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

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

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
 $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 1.00$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 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 $Esv = Es = 200000.00$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.88736994$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.88736994$
 $v = Asl,mid / (b * d) * (fsv / fc) = 1.93773$
 and confined core properties:
 $b = 90.00$
 $d = 227.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 1.67441$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 1.67441$
 $v = Asl,mid / (b * d) * (fsv / fc) = 3.65636$
 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)
 --->
 $v < s, y_1$ - LHS eq.(4.7) is not satisfied
 --->
 $v < v_{c, y_1}$ - RHS eq.(4.6) is not satisfied
 --->
 $cu (4.11) = 0.69203654$
 $MRC (4.18) = 1.9359E+008$
 --->
 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
 --->
 $v^* < v^*_{s, y_2}$ - LHS eq.(4.5) is not satisfied
 --->
 $v^* < v^*_{s, c}$ - LHS eq.(4.5) is not satisfied
 --->
 Subcase rejected
 --->
 New Subcase: Failure of compression zone
 --->
 $v^* < v^*_{c, y_2}$ - LHS eq.(4.6) is not satisfied
 --->
 $v^* < v^*_{c, y_1}$ - RHS eq.(4.6) is not satisfied

--->

*cu (4.11) = 0.73305448
MRo (4.18) = 1.3270E+008
MRo < 0.8*MRc

--->

u = cu (unconfined full section) = 1.9679130E-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 = 1.9679130E-005
Mu = 1.9359E+008

with full section properties:

b = 150.00
d = 257.00
d' = 43.00
v = 1.29793
N = 1.0007E+006
fc = 20.00
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 = 35100.00 is the 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 = 16650.00 is the unconfined core area which is equal to bi²/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00404182

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) = 0.00404182

Lstir (Length of stirrups along Y) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00404182

Lstir (Length of stirrups along X) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

s = 190.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

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

lo/lou,min = lb/lb = 1.00

su1 = 0.4*esu1_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) = 0.88736994

2 = Asl,com/(b*d)*(fs2/fc) = 0.88736994

v = Asl,mid/(b*d)*(fsv/fc) = 1.93773

and confined core properties:

b = 90.00

d = 227.00

d' = 13.00

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b*d)*(fs1/fc) = 1.67441

2 = Asl,com/(b*d)*(fs2/fc) = 1.67441

v = Asl,mid/(b*d)*(fsv/fc) = 3.65636

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)

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

$v < v_c$ - RHS eq.(4.6) is not satisfied

ϵ_{cu} (4.11) = 0.69203654

M_{Rc} (4.18) = 1.9359E+008

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

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o
- $N, \epsilon_1, \epsilon_2, v$ normalised to b_o*d_o , instead of $b*d$
- $\epsilon_c, \epsilon_{cc}$ parameters of confined concrete, f_{cc}, ϵ_{cc} used in lieu of f_c, ϵ_{cu}

Subcase: Rupture of tension steel

$v^* < v^*s_y$ - 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

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

$v^* < v^*c_x$ - RHS eq.(4.6) is not satisfied

ϵ_{cu}^* (4.11) = 0.73305448

M_{Ro} (4.18) = 1.3270E+008

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

$u = \epsilon_{cu}$ (unconfined full section) = 1.9679130E-005

$M_u = M_{Rc}$

Calculation of ratio l_b/d

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

Calculation of M_{u2}

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

$u = 1.9679130E-005$

$M_u = 1.9359E+008$

with full section properties:

$b = 150.00$

$d = 257.00$

$d' = 43.00$

$v = 1.29793$

$N = 1.0007E+006$

$f_c = 20.00$

ϵ_{co} (5A.5, TBDY) = 0.002

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

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

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

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$

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)

 $p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along Y) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

 $p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along X) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

 $s = 190.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

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

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

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

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

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

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 $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$suv = 0.032$

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) = 0.88736994
2 = Asl,com/(b*d)*(fs2/fc) = 0.88736994
v = Asl,mid/(b*d)*(fsv/fc) = 1.93773
and confined core properties:
b = 90.00
d = 227.00
d' = 13.00
fcc (5A.2, TBDY) = 20.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.67441
2 = Asl,com/(b*d)*(fs2/fc) = 1.67441
v = Asl,mid/(b*d)*(fsv/fc) = 3.65636
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) = 0.69203654
MRc (4.18) = 1.9359E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.73305448
MRo (4.18) = 1.3270E+008
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 1.9679130E-005
Mu = MRc

```

Calculation of ratio l_b/d

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

Calculation of μ_2

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

$$\mu = 1.9679130E-005$$

$$\mu_2 = 1.9359E+008$$

with full section properties:

$$b = 150.00$$

$$d = 257.00$$

$$d' = 43.00$$

$$v = 1.29793$$

$$N = 1.0007E+006$$

$$f_c = 20.00$$

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

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

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

$$\text{From (5.4b), TBDY: } \mu_c = 0.0035$$

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

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

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.00404182$$

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)

$$\mu_{psh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 660.00$$

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

$$A_{sec} \text{ (section area)} = 67500.00$$

$$\mu_{psh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along X)} = 660.00$$

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

$$A_{sec} \text{ (section area)} = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

$$s_u1 = 0.4 * e_{s1_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s1_nominal} = 0.08$,

For calculation of $e_{s1_nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $f_{sy1} = f_s/1.2$, 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.

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

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

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$s_u2 = 0.032$$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

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

$$s_u2 = 0.4 * e_{s2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s2_nominal} = 0.08$,

For calculation of $e_{s2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $f_{sy2} = f_s/1.2$, from table 5.1, TBDY.

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

$$\text{with } f_{s2} = f_s = 555.55$$

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

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

$$fy_v = 555.55$$

$$s_{uv} = 0.032$$

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

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

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

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

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

For calculation of $e_{suv_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

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

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

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

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.88736994$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.88736994$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 1.93773$$

and confined core properties:

$$b = 90.00$$

$$d = 227.00$$

$$d' = 13.00$$

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

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

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 1.67441$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 1.67441$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 3.65636$$

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) = 0.69203654
MRc (4.18) = 1.9359E+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) = 0.73305448
MRo (4.18) = 1.3270E+008
MRo < 0.8*MRc

--->

u = cu (unconfined full section) = 1.9679130E-005
Mu = MRc

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 206387.155

Calculation of Shear Strength at edge 1, Vr1 = 206387.155

Vr1 = VCol ((10.3), ASCE 41-17) = knl*VColO

VColO = 206387.155

knl = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)

fc' = 20.00, but $fc^{0.5} <= 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 1446.319

Vu = 5.7446150E-009

d = 0.8*h = 240.00

Nu = 1.0007E+006

Ag = 45000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 73486.813

where:

Vs1 = 0.00 is calculated for section web, with:

d = 120.00

Av = 157079.633

fy = 444.44

s = 190.00

Vs1 is multiplied by Col1 = 0.00

s/d = 1.58333

Vs2 = 73486.813 is calculated for section flange, with:

d = 240.00
Av = 157079.633
fy = 444.44
s = 190.00
Vs2 is multiplied by Col2 = 0.83333333
s/d = 0.79166667
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 106950.853
bw = 150.00

Calculation of Shear Strength at edge 2, Vr2 = 206387.155
Vr2 = VCol ((10.3), ASCE 41-17) = knl*VCol0
VCol0 = 206387.155
knl = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
M/Vd = 2.00
Mu = 0.02042443
Vu = 5.7446150E-009
d = 0.8*h = 240.00
Nu = 1.0007E+006
Ag = 45000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 73486.813

where:

Vs1 = 0.00 is calculated for section web, with:

d = 120.00
Av = 157079.633
fy = 444.44
s = 190.00

Vs1 is multiplied by Col1 = 0.00

s/d = 1.58333

Vs2 = 73486.813 is calculated for section flange, with:

d = 240.00
Av = 157079.633
fy = 444.44
s = 190.00

Vs2 is multiplied by Col2 = 0.83333333

s/d = 0.79166667

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

From (11-11), ACI 440: Vs + Vf <= 106950.853

bw = 150.00

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rctcs

Constant Properties

Knowledge Factor, = 0.85

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 = 20.00

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

Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$
Max Height, $H_{max} = 300.00$
Min Height, $H_{min} = 150.00$
Max Width, $W_{max} = 300.00$
Min Width, $W_{min} = 150.00$
Eccentricity, $Ecc = 75.00$
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, $M = -8.6087E+006$
Shear Force, $V_2 = -33296.807$
Shear Force, $V_3 = 8.14666$
Axial Force, $F = -998863.21$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 2375.044$
-Compression: $A_{sc} = 2777.168$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{s,ten} = 2261.947$
-Compression: $A_{s,com} = 829.3805$
-Middle: $A_{s,mid} = 2060.885$
Mean Diameter of Tension Reinforcement, $DbL = 17.77778$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{R} = \phi u = 0.03961804$
 $u = y + p = 0.04660946$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.04660946$ ((4.29), Biskinis Phd))
 $M_y = 1.5912E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 6000.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 6.8279E+012$
factor = 0.70
 $A_g = 67500.00$
 $fc' = 20.00$
 $N = 998863.21$
 $E_c * I_g = 9.7541E+012$

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, $b = 300.00$
web width, $b_w = 150.00$
flange thickness, $t = 150.00$

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 2.1411419E-005$
with $f_y = 444.44$

d = 257.00
y = 0.59616442
A = 0.25328972
B = 0.16967837
with pt = 0.00404182
pc = 0.0107572
pv = 0.02673002
N = 998863.21
b = 300.00
" = 0.16731518
y_comp = 9.3760263E-006
with fc = 20.00
Ec = 21019.039
y = 0.7107841
A = 0.1193479
B = 0.11137837
with Es = 200000.00

CONFIRMATION: $y = 0.7107841 > t/d$

Calculation of ratio l_b/d

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

- Calculation of p -

From table 10-8: $p = 0.00$

with:

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

shear control ratio $V_y E / C o l O E = 1.14818$

d = 257.00

s = 150.00

$t = A_v / (b w * s) + 2 * t_f / b w * (f_f e / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b w * (f_f e / f_s) = 0.00404182$

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

$L_{stir} = 660.00$, is the total Length of all stirrups parallel to loading (shear) direction

The term $2 * t_f / b w * (f_f e / f_s)$ 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 $f_f e / f_s$ normalises f to steel strength

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

NUD = 998863.21

$A_g = 67500.00$

$f_c E = 20.00$

$f_y t E = f_y l E = 444.44$

$p_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.06682506$

b = 300.00

d = 257.00

$f_c E = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 3

column C1, Floor 1

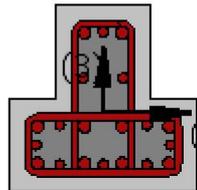
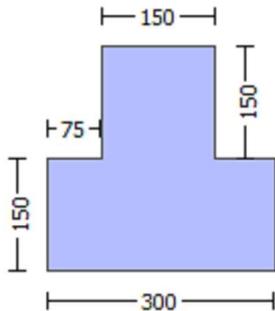
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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, $f_c = f_{c_lower_bound} = 16.00$

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

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

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

#####

Max Height, $H_{max} = 300.00$

Min Height, $H_{min} = 150.00$

Max Width, $W_{max} = 300.00$

Min Width, $W_{min} = 150.00$

Eccentricity, $Ecc = 75.00$

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 ($l_o/l_{o,min} = l_b/d \geq 1$)

No FRP Wrapping

Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = -8.6087E+006$
 Shear Force, $V_a = 8.14666$
 EDGE -B-
 Bending Moment, $M_b = -11424.291$
 Shear Force, $V_b = -8.14666$
 BOTH EDGES
 Axial Force, $F = -998863.21$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{st} = 2375.044$
 -Compression: $A_{sc} = 2777.168$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{st,ten} = 2261.947$
 -Compression: $A_{sc,com} = 829.3805$
 -Middle: $A_{sc,mid} = 2060.885$
 Mean Diameter of Tension Reinforcement, $D_{bL,ten} = 17.77778$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 109333.59$
 V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoI0} = 128627.753$
 $V_{CoI} = 128627.753$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.06148$

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

= 1 (normal-weight concrete)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa ((22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 8.6087E+006$
 $V_u = 8.14666$
 $d = 0.8 \cdot h = 240.00$
 $N_u = 998863.21$
 $A_g = 45000.00$
 From ((11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 66138.793$
 where:
 $V_{s1} = 66138.793$ is calculated for section web, with:
 $d = 240.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 190.00$
 V_{s1} is multiplied by $Col1 = 0.833333333$
 $s/d = 0.79166667$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 120.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 190.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.583333$
 V_f ((11-3)-(11.4), ACI 440) = 0.00
 From ((11-11), ACI 440: $V_s + V_f \leq 95659.751$
 $bw = 150.00$

$displacement_ductility_demand$ is calculated as ϕ / y

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

From analysis, chord rotation $\phi = 0.00286555$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.04660946$ ((4.29), Biskinis Phd))

$M_y = 1.5912E+008$
 $L_s = M/V$ (with $L_s > 0.1*L$ and $L_s < 2*L$) = 6000.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 6.8279E+012$
factor = 0.70
Ag = 67500.00
fc' = 20.00
N = 998863.21
 $E_c * I_g = 9.7541E+012$

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, $b = 300.00$
web width, $b_w = 150.00$
flange thickness, $t = 150.00$

 $y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 2.1411419E-005$
with $f_y = 444.44$
 $d = 257.00$
 $y = 0.59616442$
 $A = 0.25328972$
 $B = 0.16967837$
with $pt = 0.02933783$
 $pc = 0.0107572$
 $pv = 0.02673002$
N = 998863.21
 $b = 300.00$
 $" = 0.16731518$
 $y_{comp} = 9.3760263E-006$
with $fc = 20.00$
 $E_c = 21019.039$
 $y = 0.7107841$
 $A = 0.1193479$
 $B = 0.11137837$
with $E_s = 200000.00$
CONFIRMATION: $y = 0.7107841 > t/d$

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 TC1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 4

column C1, Floor 1

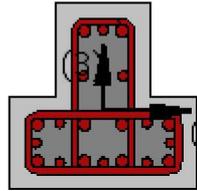
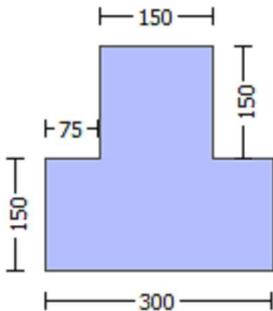
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_u)

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height, $H_{max} = 300.00$

Min Height, $H_{min} = 150.00$

Max Width, $W_{max} = 300.00$

Min Width, $W_{min} = 150.00$

Eccentricity, $E_{cc} = 75.00$

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, $V_a = -1.1623543E-006$

EDGE -B-

Shear Force, $V_b = 1.1623543E-006$

BOTH EDGES

Axial Force, $F = -1.0007E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{s,ten} = 2261.947$

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

-Middle: $A_{s,mid} = 2060.885$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.14818$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 160672.713$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.4101E+008$

$M_{u1+} = 1.4763E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.4101E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.4101E+008$

$M_{u2+} = 1.4763E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 2.4101E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of M_{u1+}

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

$\phi_u = 1.6767311E-005$

$M_u = 1.4763E+008$

with full section properties:

$b = 150.00$

$d = 257.00$

$d' = 43.00$

$v = 1.29793$

$N = 1.0007E+006$

$f_c = 20.00$

$\alpha = 0.85$ (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: $\phi_u = 0.0035$

$\phi_{ue} = 0.00$

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

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00404182$

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)

$$\text{psh}_x \text{ ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00404182$$

$$\text{Lstir (Length of stirrups along Y)} = 660.00$$

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

$$\text{Asec (section area)} = 67500.00$$

$$\text{psh}_y \text{ ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00404182$$

$$\text{Lstir (Length of stirrups along X)} = 660.00$$

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

$$\text{Asec (section area)} = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

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

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

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

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

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

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

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

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

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

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

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

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

$$fy_v = 555.55$$

$$suv = 0.032$$

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

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

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

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

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

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

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

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

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

$$1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 1.62986$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.59761649$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 1.48499$$

and confined core properties:

$$b = 90.00$$

$$d = 227.00$$

$$d' = 13.00$$

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

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

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 3.07544$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 1.12766$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 2.80207$$

Case/Assumption: Unconfined full section - Steel rupture

' does not satisfy Eq. (4.3)

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

Case/Assumption Rejected.

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

' satisfies Eq. (4.4)

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

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

$$c_u (4.11) = 0.81221594$$

$$M_{Rc} (4.18) = 1.4763E+008$$

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

In expressions below, the following modifications have been made

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

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

- - parameters of confined concrete, f_{cc}, c_c , used in lieu of f_c, c_u

Subcase: Rupture of tension steel

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

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

Subcase rejected

New Subcase: Failure of compression zone

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

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

$$*c_u (4.11) = 0.91366546$$

$$M_{Ro} (4.18) = 8.4535E+007$$

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

$$u = c_u (\text{unconfined full section}) = 1.6767311E-005$$

$$M_u = M_{Rc}$$

Calculation of ratio l_b/d

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

Calculation of M_{u1} -

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

$$\mu = 1.8792920E-005$$

$$M_u = 2.4101E+008$$

with full section properties:

$$b = 300.00$$

$$d = 257.00$$

$$d' = 43.00$$

$$v = 0.64896668$$

$$N = 1.0007E+006$$

$$f_c = 20.00$$

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

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

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

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

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

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

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00404182$$

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

$$\phi_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 660.00$$

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

$$A_{sec} \text{ (section area)} = 67500.00$$

$$\phi_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along X)} = 660.00$$

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

$$A_{sec} \text{ (section area)} = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

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

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

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

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$, from 10.3.5, 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/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) = 0.29880825
2 = Asl,com/(b*d)*(fs2/fc) = 0.81493158
v = Asl,mid/(b*d)*(fsv/fc) = 0.74249322
and confined core properties:
b = 240.00
d = 227.00
d' = 13.00
fcc (5A.2, TBDY) = 20.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.4228729
2 = Asl,com/(b*d)*(fs2/fc) = 1.15329
v = Asl,mid/(b*d)*(fsv/fc) = 1.05078
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) = 0.45266836
MRc (4.17) = 2.7366E+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) = 0.46882405

MRo (4.18) = 2.4101E+008

--->

u = cu (4.2) = 1.8792920E-005

Mu = MRo

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

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

u = 1.6767311E-005

Mu = 1.4763E+008

with full section properties:

b = 150.00

d = 257.00

d' = 43.00

v = 1.29793

N = 1.0007E+006

fc = 20.00

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 = 35100.00 is the 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 = 16650.00 is the unconfined core area which is equal to bi²/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00404182

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) = 0.00404182

Lstir (Length of stirrups along Y) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00404182

Lstir (Length of stirrups along X) = 660.00
Astir (stirrups area) = 78.53982
Asec (section area) = 67500.00

s = 190.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

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

lo/lou,min = lb/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) = 1.62986

2 = Asl,com/(b*d)*(fs2/fc) = 0.59761649

v = Asl,mid/(b*d)*(fsv/fc) = 1.48499

and confined core properties:

b = 90.00

d = 227.00

d' = 13.00

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00
1 = $Asl,ten/(b*d)*(fs1/fc) = 3.07544$
2 = $Asl,com/(b*d)*(fs2/fc) = 1.12766$
v = $Asl,mid/(b*d)*(fsv/fc) = 2.80207$

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) = 0.81221594
MRc (4.18) = 1.4763E+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) = 0.91366546
MRo (4.18) = 8.4535E+007

MRo < 0.8*MRc

---->
u = cu (unconfined full section) = 1.6767311E-005
Mu = MRc

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.8792920E-005
Mu = 2.4101E+008

with full section properties:
b = 300.00
d = 257.00
d' = 43.00

$$v = 0.64896668$$

$$N = 1.0007E+006$$

$$fc = 20.00$$

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

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

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

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

$$we (5.4c) = 0.00$$

$$ase = \text{Max}(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.00$$

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., 10.11061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max = 35100.00 is the 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 = 16650.00 is the unconfined core area which is equal to $bi^2/6$ as defined at (A.2).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00404182$$

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)

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00404182$$

$$Lstir (\text{Length of stirrups along } Y) = 660.00$$

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

$$Asec (\text{section area}) = 67500.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00404182$$

$$Lstir (\text{Length of stirrups along } X) = 660.00$$

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

$$Asec (\text{section area}) = 67500.00$$

$$s = 190.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

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

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

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

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

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

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

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

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

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

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

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

$$y2 = 0.00231479$$

$$sh2 = 0.008$$

$$ft2 = 666.66$$

$$fy2 = 555.55$$

$$su2 = 0.032$$

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 $f_{s2} = f_s/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, 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 $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY

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

characteristic value $f_{sv} = f_{sv}/1.2$, 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 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.29880825$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.81493158$

$v = Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.74249322$

and confined core properties:

$b = 240.00$

$d = 227.00$

$d' = 13.00$

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

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

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

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.4228729$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 1.15329$

$v = Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 1.05078$

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

--->

$cu (4.10) = 0.45266836$

$M_{Rc} (4.17) = 2.7366E+008$

--->

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

--->

*cu (4.11) = 0.46882405

M_{Ro} (4.18) = 2.4101E+008

--->

u = cu (4.2) = 1.8792920E-005

Mu = M_{Ro}

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 139936.984$

Calculation of Shear Strength at edge 1, $V_{r1} = 139936.984$

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

V_{Col0} = 139936.984

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)

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

M/Vd = 4.00

Mu = 934188.794

Vu = 1.1623543E-006

d = 0.8*h = 240.00

Nu = 1.0007E+006

Ag = 45000.00

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

$V_{s1} = 73486.813$ is calculated for section web, with:

d = 240.00

Av = 157079.633

fy = 444.44

s = 190.00

V_{s1} is multiplied by Col1 = 0.83333333

s/d = 0.79166667

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

d = 120.00

Av = 157079.633

fy = 444.44

s = 190.00

V_{s2} is multiplied by Col2 = 0.00

s/d = 1.58333

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

From (11-11), ACI 440: $V_s + V_f \leq 106950.853$

bw = 150.00

Calculation of Shear Strength at edge 2, $V_{r2} = 139936.984$

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

V_{Col0} = 139936.984

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)

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

$M/Vd = 4.00$
 $\mu_u = 760.756$
 $V_u = 1.1623543E-006$
 $d = 0.8 \cdot h = 240.00$
 $N_u = 1.0007E+006$
 $A_g = 45000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$
 where:
 $V_{s1} = 73486.813$ is calculated for section web, with:
 $d = 240.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 190.00$
 V_{s1} is multiplied by $Col1 = 0.83333333$
 $s/d = 0.79166667$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 120.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 190.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.58333$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
 From (11-11), ACI 440: $V_s + V_f \leq 106950.853$
 $b_w = 150.00$

 End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
 At local axis: 3

 Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rctcs

Constant Properties

 Knowledge Factor, $\phi = 0.85$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$
 #####
 Max Height, $H_{max} = 300.00$
 Min Height, $H_{min} = 150.00$
 Max Width, $W_{max} = 300.00$
 Min Width, $W_{min} = 150.00$
 Eccentricity, $Ecc = 75.00$
 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, $V_a = -5.7446150E-009$

EDGE -B-

Shear Force, $V_b = 5.7446150E-009$

BOTH EDGES

Axial Force, $F = -1.0007E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1231.504$

-Compression: $As_{c,com} = 1231.504$

-Middle: $As_{c,mid} = 2689.203$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.62533189$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 129060.47$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.9359E+008$

$Mu_{1+} = 1.9359E+008$, 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

$Mu_{1-} = 1.9359E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.9359E+008$

$Mu_{2+} = 1.9359E+008$, 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

$Mu_{2-} = 1.9359E+008$, 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:

$\phi_u = 1.9679130E-005$

$M_u = 1.9359E+008$

with full section properties:

$b = 150.00$

$d = 257.00$

$d' = 43.00$

$v = 1.29793$

$N = 1.0007E+006$

$f_c = 20.00$

ω (5A.5, TBDY) = 0.002

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

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

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

ω_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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$

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)

 $p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along Y) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

 $p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along X) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

 $s = 190.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

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

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

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

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

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

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

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

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

with $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

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

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

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

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

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

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

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$su_v = 0.032$

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

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

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

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

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

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

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

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

with $f_{sv} = f_s = 555.55$

with $E_{sv} = E_s = 200000.00$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.88736994$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.88736994$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 1.93773$

and confined core properties:

$b = 90.00$

$d = 227.00$

$d' = 13.00$

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

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 1.67441$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 1.67441$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 3.65636$

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

--->

$\ast cu$ (4.11) = 0.69203654

M_{Rc} (4.18) = 1.9359E+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, 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

--->

$\ast cu$ (4.11) = 0.73305448

M_{Ro} (4.18) = 1.3270E+008

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

--->

$u = cu$ (unconfined full section) = 1.9679130E-005

$M_u = M_{Rc}$

Calculation of ratio l_b/d

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

Calculation of Mu1-

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

$$\mu = 1.9679130E-005$$

$$Mu = 1.9359E+008$$

with full section properties:

$$b = 150.00$$

$$d = 257.00$$

$$d' = 43.00$$

$$v = 1.29793$$

$$N = 1.0007E+006$$

$$f_c = 20.00$$

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

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

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 660.00$$

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

$$A_{sec} \text{ (section area)} = 67500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along X)} = 660.00$$

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

$$A_{sec} \text{ (section area)} = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

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

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

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

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

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

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
 $lo/lo_{min} = lb/lb_{min} = 1.00$
 $su_2 = 0.4 * esu_{2_nominal} ((5.5), TBDY) = 0.032$
 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 $fs_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_2 = fs = 555.55$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00231479$
 $sh_v = 0.008$
 $ft_v = 666.66$
 $fy_v = 555.55$
 $su_v = 0.032$
 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
 $lo/lo_{min} = lb/d = 1.00$
 $su_v = 0.4 * esu_{v_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{v_nominal} = 0.08$,
 considering characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY
 For calculation of $esu_{v_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_v = fs = 555.55$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.88736994$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.88736994$
 $v = A_{sl,mid}/(b*d) * (fs_v/f_c) = 1.93773$
 and confined core properties:
 $b = 90.00$
 $d = 227.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 1.67441$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 1.67441$
 $v = A_{sl,mid}/(b*d) * (fs_v/f_c) = 3.65636$
 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
 --->
 $cu (4.11) = 0.69203654$
 $M_{Rc} (4.18) = 1.9359E+008$
 --->
 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}, c_c , used in lieu of f_c, e_{cu}

---->
Subcase: Rupture of tension steel

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

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

---->
Subcase rejected

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

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

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

---->
 μ_{cu} (4.11) = 0.73305448

M_{Ro} (4.18) = 1.3270E+008

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

---->
 $u = \mu_{cu}$ (unconfined full section) = 1.9679130E-005
 $\mu_u = M_{Rc}$

Calculation of ratio l_b/l_d

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

Calculation of μ_{u2+}

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

$u = 1.9679130E-005$

$\mu_u = 1.9359E+008$

with full section properties:

$b = 150.00$

$d = 257.00$

$d' = 43.00$

$v = 1.29793$

$N = 1.0007E+006$

$f_c = 20.00$

μ_{co} (5A.5, TBDY) = 0.002

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

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

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

we (5.4c) = 0.00

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

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.00404182$

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)

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00404182$$

$$Lstir (\text{Length of stirrups along } Y) = 660.00$$

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

$$Asec (\text{section area}) = 67500.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00404182$$

$$Lstir (\text{Length of stirrups along } X) = 660.00$$

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

$$Asec (\text{section area}) = 67500.00$$

$$s = 190.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

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

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

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

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

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

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

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

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

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

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

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

$$y2 = 0.00231479$$

$$sh2 = 0.008$$

$$ft2 = 666.66$$

$$fy2 = 555.55$$

$$su2 = 0.032$$

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

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

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

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

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

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

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

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

$$yv = 0.00231479$$

$$shv = 0.008$$

$$ftv = 666.66$$

$$fyv = 555.55$$

$$suv = 0.032$$

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

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

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

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

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

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

$$yv, shv,ftv,fyv, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

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

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.88736994$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.88736994$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 1.93773$$

and confined core properties:

$$b = 90.00$$

$$d = 227.00$$

$$d' = 13.00$$

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

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

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 1.67441$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 1.67441$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 3.65636$$

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

---->

$$cu (4.11) = 0.69203654$$

$$MRc (4.18) = 1.9359E+008$$

---->

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 $b*d$

- 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

---->

$$*cu (4.11) = 0.73305448$$

$$MRo (4.18) = 1.3270E+008$$

$$MRo < 0.8*MRc$$

---->

$$u = cu (\text{unconfined full section}) = 1.9679130E-005$$

$$Mu = MRc$$

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:

$$u = 1.9679130E-005$$

Mu = 1.9359E+008

with full section properties:

b = 150.00

d = 257.00

d' = 43.00

v = 1.29793

N = 1.0007E+006

fc = 20.00

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

$ase = \text{Max}(((Aconf,max - AnoConf) / Aconf,max) * (Aconf,min / Aconf,max), 0) = 0.00$

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 = 35100.00 is the 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 = 16650.00 is the unconfined core area which is equal to $bi^2/6$ as defined at (A.2).

psh,min = $\text{Min}(psh,x, psh,y) = 0.00404182$

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) = $Lstir * Astir / (Asec * s) = 0.00404182$

Lstir (Length of stirrups along Y) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

psh,y ((5.4d), TBDY) = $Lstir * Astir / (Asec * s) = 0.00404182$

Lstir (Length of stirrups along X) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

s = 190.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

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

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

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

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

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

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, 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
 $l_o/l_{o,min} = l_b/l_{b,min} = 1.00$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, 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
 $l_o/l_{o,min} = l_b/l_d = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
considering characteristic value $fsy_v = fs_v/1.2$, from table 5.1, TBDY
For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsy_v = fs_v/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
with $fs_v = fs = 555.55$
with $Es_v = Es = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.88736994$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.88736994$
 $v = A_{sl,mid}/(b*d) * (fs_v/f_c) = 1.93773$
and confined core properties:
 $b = 90.00$
 $d = 227.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 1.67441$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 1.67441$
 $v = A_{sl,mid}/(b*d) * (fs_v/f_c) = 3.65636$
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
---->
 $cu (4.11) = 0.69203654$
 $M_{Rc} (4.18) = 1.9359E+008$
---->
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 $b*d$
- 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

--->

μ_{cu} (4.11) = 0.73305448

M_{Ro} (4.18) = 1.3270E+008

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

--->

$\mu = \mu_{cu}$ (unconfined full section) = 1.9679130E-005

$\mu_u = M_{Rc}$

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 206387.155$

Calculation of Shear Strength at edge 1, $V_{r1} = 206387.155$

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

$V_{Co10} = 206387.155$

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

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

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

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

$M/Vd = 2.00$

$\mu_u = 1446.319$

$V_u = 5.7446150E-009$

$d = 0.8 \cdot h = 240.00$

$N_u = 1.0007E+006$

$A_g = 45000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

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

$d = 120.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 190.00$

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

$s/d = 1.58333$

$V_{s2} = 73486.813$ is calculated for section flange, with:

$d = 240.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 190.00$

V_{s2} is multiplied by $Col2 = 0.833333333$

$s/d = 0.791666667$

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

From (11-11), ACI 440: $V_s + V_f \leq 106950.853$

$b_w = 150.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 206387.155$

$V_{r2} = V_{Co2}$ ((10.3), ASCE 41-17) = $k_n l \cdot V_{Co20}$

$V_{Co20} = 206387.155$

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

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

= 1 (normal-weight concrete)

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

$M/Vd = 2.00$

$\mu_u = 0.02042443$

$V_u = 5.7446150E-009$

$d = 0.8 \cdot h = 240.00$

$N_u = 1.0007E+006$

$A_g = 45000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

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

$d = 120.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 190.00$

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

$s/d = 1.58333$

$V_{s2} = 73486.813$ is calculated for section flange, with:

$d = 240.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 190.00$

V_{s2} is multiplied by $Col2 = 0.83333333$

$s/d = 0.79166667$

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

From (11-11), ACI 440: $V_s + V_f \leq 106950.853$

$b_w = 150.00$

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1
At local axis: 3
Integration Section: (a)
Section Type: rctcs

Constant Properties

Knowledge Factor, $\phi = 0.85$

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, $f_c = f_{cm} = 20.00$

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 300.00$

Min Height, $H_{min} = 150.00$

Max Width, $W_{max} = 300.00$

Min Width, $W_{min} = 150.00$

Eccentricity, $Ecc = 75.00$

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, $M = -2.1593E+008$
Shear Force, $V_2 = -33296.807$
Shear Force, $V_3 = 8.14666$
Axial Force, $F = -998863.21$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 2375.044$
-Compression: $A_{sc} = 2777.168$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten} = 1231.504$
-Compression: $A_{sc,com} = 1231.504$
-Middle: $A_{st,mid} = 2689.203$
Mean Diameter of Tension Reinforcement, $D_bL = 17.60$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = * u = 0.03357584$
 $u = y + p = 0.03950098$

- Calculation of y -

 $y = (M_y * L_s / 3) / E_{eff} = 0.03950098$ ((4.29), Biskinis Phd)
 $M_y = 1.1034E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 6000.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 5.5865E+012$
factor = 0.70
Ag = 67500.00
fc' = 20.00
N = 998863.21
 $E_c * I_g = 7.9807E+012$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

 $y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 2.2096501E-005$
with $f_y = 444.44$
d = 257.00
 $y = 0.60868498$
A = 0.19195011
B = 0.1363059
with $p_t = 0.00404182$
pc = 0.03194564
pv = 0.06975884
N = 998863.21
b = 150.00
" = 0.16731518
 $y_{comp} = 8.4828072E-006$
with $f_c = 20.00$
Ec = 21019.039
 $y = 0.78562795$
A = 0.05800829
B = 0.0780059
with $E_s = 200000.00$

Calculation of ratio l_b/d

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

- Calculation of ρ -

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

with:

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

shear control ratio $V_y E / V_{CoI} E = 0.62533189$

$d = 257.00$

$s = 150.00$

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00404182$

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

$L_{stir} = 660.00$, 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.

$NUD = 998863.21$

$A_g = 67500.00$

$f_{cE} = 20.00$

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

$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.13365012$

$b = 150.00$

$d = 257.00$

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 5

column C1, Floor 1

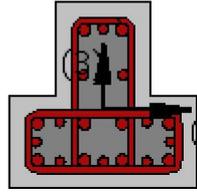
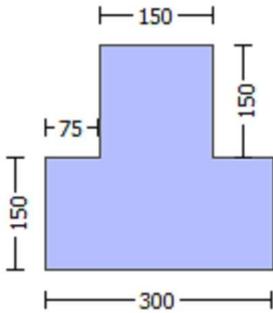
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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, $f_c = f_{c_lower_bound} = 16.00$

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

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

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

#####

Max Height, $H_{max} = 300.00$

Min Height, $H_{min} = 150.00$

Max Width, $W_{max} = 300.00$

Min Width, $W_{min} = 150.00$

Eccentricity, $Ecc = 75.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

No FRP Wrapping

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -2.1593E+008$

Shear Force, $V_a = -33296.807$

EDGE -B-

Bending Moment, $M_b = -6.6728E+006$

Shear Force, $V_b = 33296.807$

BOTH EDGES

Axial Force, $F = -998863.21$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1231.504$
-Compression: $A_{sl,com} = 1231.504$
-Middle: $A_{sl,mid} = 2689.203$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.60$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 113714.444$
 V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoIO} = 133781.699$
 $V_{CoI} = 191116.713$
 $k_n = 0.70$
 $displacement_ductility_demand = 6.51624$

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

= 1 (normal-weight concrete)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 6.6728E+006$
 $V_u = 33296.807$
 $d = 0.8 \cdot h = 240.00$
 $N_u = 998863.21$
 $A_g = 45000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 66138.793$
where:
 $V_{s1} = 0.00$ is calculated for section web, with:
 $d = 120.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 190.00$
 V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 1.58333$
 $V_{s2} = 66138.793$ is calculated for section flange, with:
 $d = 240.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 190.00$
 V_{s2} is multiplied by $Col2 = 0.83333333$
 $s/d = 0.79166667$
 V_f ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: $V_s + V_f \leq 95659.751$
 $bw = 150.00$

$displacement_ductility_demand$ is calculated as ϕ / y

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

From analysis, chord rotation $\theta = 0.01286989$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00197505$ ((4.29), Biskinis Phd)
 $M_y = 1.1034E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 5.5865E+012$
 $factor = 0.70$
 $A_g = 67500.00$
 $f_c' = 20.00$
 $N = 998863.21$
 $E_c \cdot I_g = 7.9807E+012$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 2.2096501\text{E-}005$
with $f_y = 444.44$
 $d = 257.00$
 $y = 0.60868498$
 $A = 0.19195011$
 $B = 0.1363059$
with $p_t = 0.03194564$
 $p_c = 0.03194564$
 $p_v = 0.06975884$
 $N = 998863.21$
 $b = 150.00$
 $\mu = 0.16731518$
 $y_{\text{comp}} = 8.4828072\text{E-}006$
with $f_c = 20.00$
 $E_c = 21019.039$
 $y = 0.78562795$
 $A = 0.05800829$
 $B = 0.0780059$
with $E_s = 200000.00$

Calculation of ratio l_b/d

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

End Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 6

column C1, Floor 1

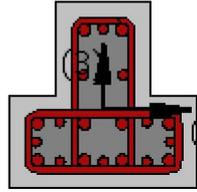
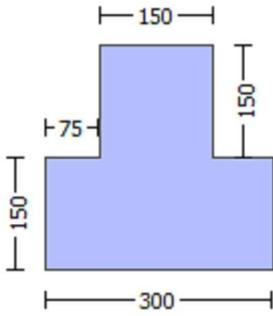
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_u)

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At Shear local axis: 3
 (Bending local axis: 2)
 Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height, $H_{max} = 300.00$

Min Height, $H_{min} = 150.00$

Max Width, $W_{max} = 300.00$

Min Width, $W_{min} = 150.00$

Eccentricity, $Ecc = 75.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.00

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

No FRP Wrapping

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = -1.1623543E-006$

EDGE -B-

Shear Force, $V_b = 1.1623543E-006$

BOTH EDGES

Axial Force, $F = -1.0007E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{st,ten} = 2261.947$

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

-Middle: $A_{st,mid} = 2060.885$

Calculation of Shear Capacity ratio , $V_e/V_r = 1.14818$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 160672.713$

with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 2.4101E+008$

$\mu_{1+} = 1.4763E+008$, 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

$\mu_{1-} = 2.4101E+008$, 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 2.4101E+008$

$\mu_{2+} = 1.4763E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$\mu_{2-} = 2.4101E+008$, 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:

$\mu = 1.6767311E-005$

$M_u = 1.4763E+008$

with full section properties:

$b = 150.00$

$d = 257.00$

$d' = 43.00$

$v = 1.29793$

$N = 1.0007E+006$

$f_c = 20.00$

α_0 (5A.5, TBDY) = 0.002

Final value of α_0 : $\alpha_0^* = \text{shear_factor} * \text{Max}(\alpha_0, \alpha_c) = 0.0035$

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

From (5.4b), TBDY: $\alpha_0 = 0.0035$

α_w (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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$\rho_{sh,min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.00404182$

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

$\rho_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along Y) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

$\rho_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along X) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

$s = 190.00$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

$$su_1 = 0.4 * esu_1 \text{ nominal ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu_1 \text{ nominal} = 0.08$,

For calculation of $esu_1 \text{ nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

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

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

$$su_2 = 0.4 * esu_2 \text{ nominal ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu_2 \text{ nominal} = 0.08$,

For calculation of $esu_2 \text{ nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

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

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

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

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

$$fy_v = 555.55$$

$$su_v = 0.032$$

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

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

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

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

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

For calculation of $esuv \text{ nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

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

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

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

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 1.62986$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.59761649$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 1.48499$$

and confined core properties:

$$b = 90.00$$

$$d = 227.00$$

$$d' = 13.00$$

$$fcc \text{ (5A.2, TBDY)} = 20.00$$

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

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

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 3.07544$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 1.12766$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 2.80207$$

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)

---->

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

---->

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

---->

ϵ_{cu} (4.11) = 0.81221594

M_{Rc} (4.18) = 1.4763E+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 , ϵ_1 , ϵ_2 , v normalised to $b_o \cdot d_o$, instead of $b \cdot d$
- ϵ_c , 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

---->

ϵ^*_{cu} (4.11) = 0.91366546

M_{Ro} (4.18) = 8.4535E+007

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

---->

$\epsilon_u = \epsilon_{cu}$ (unconfined full section) = 1.6767311E-005

$\mu_u = M_{Rc}$

Calculation of ratio l_b/d

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

Calculation of μ_{u1} -

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

$\epsilon_u = 1.8792920E-005$

$\mu_u = 2.4101E+008$

with full section properties:

$b = 300.00$

$d = 257.00$

$d' = 43.00$

$v = 0.64896668$

$N = 1.0007E+006$

$f_c = 20.00$

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: $c_u = 0.0035$

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along Y) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along X) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

$s = 190.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

c = confinement factor = 1.00

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

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

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

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

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

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

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

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

$su_2 = 0.4 * esu2_{nominal}$ ((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/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) = 0.29880825
2 = Asl,com/(b*d)*(fs2/fc) = 0.81493158
v = Asl,mid/(b*d)*(fsv/fc) = 0.74249322
and confined core properties:
b = 240.00
d = 227.00
d' = 13.00
fcc (5A.2, TBDY) = 20.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.4228729
2 = Asl,com/(b*d)*(fs2/fc) = 1.15329
v = Asl,mid/(b*d)*(fsv/fc) = 1.05078
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) = 0.45266836
MRC (4.17) = 2.7366E+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) = 0.46882405

```

$$M_{Ro} (4.18) = 2.4101E+008$$

--->

$$u = c_u (4.2) = 1.8792920E-005$$

$$\mu = M_{Ro}$$

Calculation of ratio l_b/d

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

Calculation of μ_{2+}

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

$$u = 1.6767311E-005$$

$$\mu = 1.4763E+008$$

with full section properties:

$$b = 150.00$$

$$d = 257.00$$

$$d' = 43.00$$

$$v = 1.29793$$

$$N = 1.0007E+006$$

$$f_c = 20.00$$

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

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

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

$$\text{From (5.4b), TBDY: } c_u = 0.0035$$

$$w_e (5.4c) = 0.00$$

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

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$$

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)

 $p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

$$L_{stir} (\text{Length of stirrups along Y}) = 660.00$$

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

$$A_{sec} (\text{section area}) = 67500.00$$

 $p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

$$L_{stir} (\text{Length of stirrups along X}) = 660.00$$

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

$$A_{sec} (\text{section area}) = 67500.00$$

 $s = 190.00$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

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) = 1.62986

2 = Asl,com/(b*d)*(fs2/fc) = 0.59761649

v = Asl,mid/(b*d)*(fsv/fc) = 1.48499

and confined core properties:

b = 90.00

d = 227.00

d' = 13.00

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b*d)*(fs1/fc) = 3.07544

2 = Asl,com/(b*d)*(fs2/fc) = 1.12766

v = Asl,mid/(b*d)*(fsv/fc) = 2.80207

Case/Assumption: Unconfined full section - Steel rupture

' does not satisfy Eq. (4.3)

--->

v < vs,c - RHS eq.(4.5) is not satisfied

--->

Case/Assumption Rejected.

--->

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

' satisfies Eq. (4.4)

--->
 $v < s_y1$ - LHS eq.(4.7) is not satisfied
 --->
 $v < v_c y1$ - RHS eq.(4.6) is not satisfied
 --->
 c_u (4.11) = 0.81221594
 M_{Rc} (4.18) = 1.4763E+008
 --->
 New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
 In expressions below, the following modifications have been made
 - b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o
 - $N, 1, 2, v$ normalised to $b_o * d_o$, instead of $b * d$
 - f_{cc}, c_c parameters of confined concrete, f_{cc}, c_c , used in lieu of f_c, c_u

--->
Subcase: Rupture of tension steel

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

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

--->
Subcase rejected

--->
New Subcase: Failure of compression zone

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

--->
 $v^* < v^* c_y1$ - RHS eq.(4.6) is not satisfied

--->
 $*c_u$ (4.11) = 0.91366546
 M_{Ro} (4.18) = 8.4535E+007

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

--->
 $u = c_u$ (unconfined full section) = 1.6767311E-005

$M_u = M_{Rc}$

Calculation of ratio I_b/I_d

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

Calculation of M_{u2}

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

$u = 1.8792920E-005$

$M_u = 2.4101E+008$

with full section properties:

$b = 300.00$

$d = 257.00$

$d' = 43.00$

$v = 0.64896668$

$N = 1.0007E+006$

$f_c = 20.00$

c_o (5A.5, TBDY) = 0.002

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

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

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

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh,min = \text{Min}(psh,x, psh,y) = 0.00404182$

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

 psh,x ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along Y) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

 psh,y ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along X) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

 $s = 190.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

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

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

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

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

$su_1 = 0.4 * esu1_{nominal}$ ((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 $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$su_v = 0.032$

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

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

$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 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 $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.29880825$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.81493158$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.74249322$
 and confined core properties:
 $b = 240.00$
 $d = 227.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.4228729$
 $2 = Asl,com/(b*d)*(fs2/fc) = 1.15329$
 $v = Asl,mid/(b*d)*(fsv/fc) = 1.05078$
 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
 --->
 $cu (4.10) = 0.45266836$
 $MRC (4.17) = 2.7366E+008$
 --->
 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 $b*d$
 - fcc, cc 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
 --->
 $*cu (4.11) = 0.46882405$
 $MRO (4.18) = 2.4101E+008$
 --->
 $u = cu (4.2) = 1.8792920E-005$
 $Mu = MRO$

 Calculation of ratio lb/ld

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 139936.984$

Calculation of Shear Strength at edge 1, $V_{r1} = 139936.984$

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

$V_{Co10} = 139936.984$

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

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

= 1 (normal-weight concrete)

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

$M/Vd = 4.00$

$M_u = 934188.794$

$V_u = 1.1623543E-006$

$d = 0.8 * h = 240.00$

$N_u = 1.0007E+006$

$A_g = 45000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

$V_{s1} = 73486.813$ is calculated for section web, with:

$d = 240.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 190.00$

V_{s1} is multiplied by $Col1 = 0.83333333$

$s/d = 0.79166667$

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

$d = 120.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 190.00$

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

$s/d = 1.58333$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 0.00$

From (11-11), ACI 440: $V_s + V_f \leq 106950.853$

$b_w = 150.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 139936.984$

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

$V_{Co10} = 139936.984$

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

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

= 1 (normal-weight concrete)

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

$M/Vd = 4.00$

$M_u = 760.756$

$V_u = 1.1623543E-006$

$d = 0.8 * h = 240.00$

$N_u = 1.0007E+006$

$A_g = 45000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

$V_{s1} = 73486.813$ is calculated for section web, with:

$d = 240.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 190.00$

Vs1 is multiplied by Col1 = 0.83333333
s/d = 0.79166667
Vs2 = 0.00 is calculated for section flange, with:
d = 120.00
Av = 157079.633
fy = 444.44
s = 190.00
Vs2 is multiplied by Col2 = 0.00
s/d = 1.58333
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 106950.853
bw = 150.00

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rctcs

Constant Properties

Knowledge Factor, = 0.85
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00
Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44
Concrete Elasticity, Ec = 21019.039
Steel Elasticity, Es = 200000.00

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

Max Height, Hmax = 300.00
Min Height, Hmin = 150.00
Max Width, Wmax = 300.00
Min Width, Wmin = 150.00
Eccentricity, Ecc = 75.00
Cover Thickness, c = 25.00
Mean Confinement Factor overall section = 1.00
Element Length, L = 3000.00
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length (lo/lou,min >= 1)
No FRP Wrapping

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, Va = -5.7446150E-009
EDGE -B-
Shear Force, Vb = 5.7446150E-009
BOTH EDGES
Axial Force, F = -1.0007E+006
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00

-Compression: $A_{s,c} = 5152.212$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{s,t} = 1231.504$
-Compression: $A_{s,c} = 1231.504$
-Middle: $A_{s,m} = 2689.203$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.62533189$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 129060.47$
with

$M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 1.9359E+008$
 $M_{u1+} = 1.9359E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $M_{u1-} = 1.9359E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 1.9359E+008$
 $M_{u2+} = 1.9359E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination
 $M_{u2-} = 1.9359E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of M_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 1.9679130E-005$
 $M_u = 1.9359E+008$

with full section properties:

$b = 150.00$
 $d = 257.00$
 $d' = 43.00$
 $\nu = 1.29793$
 $N = 1.0007E+006$
 $f_c = 20.00$
 ϕ_c (5A.5, TBDY) = 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), TBDY: $\phi_c = 0.0035$
 ϕ_w (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.
 $A_{conf,max} = 35100.00$ is the 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.
 $A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $\phi_{psh,min} = \text{Min}(\phi_{psh,x} , \phi_{psh,y}) = 0.00404182$
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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$
 L_{stir} (Length of stirrups along Y) = 660.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 67500.00

$\phi_{psh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

Lstir (Length of stirrups along X) = 660.00
Astir (stirrups area) = 78.53982
Asec (section area) = 67500.00

s = 190.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

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

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

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

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

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

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

with fs1 = fs = 555.55

with Es1 = Es = 200000.00

y2 = 0.00231479

sh2 = 0.008

ft2 = 666.66

fy2 = 555.55

su2 = 0.032

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

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

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

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

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

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

with fs2 = fs = 555.55

with Es2 = Es = 200000.00

yv = 0.00231479

shv = 0.008

ftv = 666.66

fyv = 555.55

suv = 0.032

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

lo/lou,min = lb/ld = 1.00

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

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

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

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

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

with fsv = fs = 555.55

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.88736994

2 = Asl,com/(b*d)*(fs2/fc) = 0.88736994

v = Asl,mid/(b*d)*(fsv/fc) = 1.93773

and confined core properties:

b = 90.00

d = 227.00

d' = 13.00

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00
1 = $Asl,ten/(b*d)*(fs1/fc) = 1.67441$
2 = $Asl,com/(b*d)*(fs2/fc) = 1.67441$
v = $Asl,mid/(b*d)*(fsv/fc) = 3.65636$

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) = 0.69203654
MRc (4.18) = 1.9359E+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) = 0.73305448
MRo (4.18) = 1.3270E+008

MRo < 0.8*MRc

---->
u = cu (unconfined full section) = 1.9679130E-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 = 1.9679130E-005
Mu = 1.9359E+008

with full section properties:

b = 150.00
d = 257.00
d' = 43.00

$$v = 1.29793$$

$$N = 1.0007E+006$$

$$f_c = 20.00$$

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

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

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

$$\text{From (5.4b), TBDY: } c_u = 0.0035$$

$$w_e (5.4c) = 0.00$$

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

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., 10.11061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} (\text{Length of stirrups along Y}) = 660.00$$

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

$$A_{sec} (\text{section area}) = 67500.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} (\text{Length of stirrups along X}) = 660.00$$

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

$$A_{sec} (\text{section area}) = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

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

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

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

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

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

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

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

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

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

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

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

For calculation of $esu2_{nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered

characteristic value $f_{s2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, 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 $E_{s2} = E_s = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$s_{uv} = 0.032$

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

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

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

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

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

For calculation of $e_{suv_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

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

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

with $f_{sv} = f_s = 555.55$

with $E_{sv} = E_s = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.88736994$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.88736994$

$v = Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 1.93773$

and confined core properties:

$b = 90.00$

$d = 227.00$

$d' = 13.00$

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

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

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

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 1.67441$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 1.67441$

$v = Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 3.65636$

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

--->

$cu (4.11) = 0.69203654$

$M_{Rc} (4.18) = 1.9359E+008$

--->

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

--->

*cu (4.11) = 0.73305448

M_{Ro} (4.18) = 1.3270E+008

M_{Ro} < 0.8*M_{Rc}

--->

u = cu (unconfined full section) = 1.9679130E-005

Mu = M_{Rc}

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 = 1.9679130E-005

Mu = 1.9359E+008

with full section properties:

b = 150.00

d = 257.00

d' = 43.00

v = 1.29793

N = 1.0007E+006

f_c = 20.00

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(((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} = 35100.00 is the 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} = 16650.00 is the unconfined core area which is equal to bi²/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00404182

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

psh,x ((5.4d), TBDY) = L_{stir}*A_{stir}/(A_{sec}*s) = 0.00404182

L_{stir} (Length of stirrups along Y) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

psh,y ((5.4d), TBDY) = L_{stir}*A_{stir}/(A_{sec}*s) = 0.00404182

L_{stir} (Length of stirrups along X) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

s = 190.00

f_{ywe} = 555.55

f_{ce} = 20.00

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

$y1 = 0.00231479$

$sh1 = 0.008$

$ft1 = 666.66$

$fy1 = 555.55$

$su1 = 0.032$

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

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

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

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

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

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, 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 $Esv = Es = 200000.00$

$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.88736994$

$2 = Asl,com / (b * d) * (fs2 / fc) = 0.88736994$

$v = Asl,mid / (b * d) * (fsv / fc) = 1.93773$

and confined core properties:

$b = 90.00$

$d = 227.00$

$d' = 13.00$

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

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

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

$1 = Asl,ten / (b * d) * (fs1 / fc) = 1.67441$

$2 = Asl,com / (b * d) * (fs2 / fc) = 1.67441$

$v = Asl,mid / (b * d) * (fsv / fc) = 3.65636$

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) = 0.69203654

M_{Rc} (4.18) = 1.9359E+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

--->

*cu (4.11) = 0.73305448

M_{Ro} (4.18) = 1.3270E+008

M_{Ro} < 0.8*M_{Rc}

--->

u = cu (unconfined full section) = 1.9679130E-005

Mu = M_{Rc}

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 = 1.9679130E-005

Mu = 1.9359E+008

with full section properties:

b = 150.00

d = 257.00

d' = 43.00

v = 1.29793

N = 1.0007E+006

f_c = 20.00

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} (\text{Length of stirrups along Y}) = 660.00$$

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

$$A_{sec} (\text{section area}) = 67500.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} (\text{Length of stirrups along X}) = 660.00$$

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

$$A_{sec} (\text{section area}) = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

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

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

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

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

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

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

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/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) = 0.88736994
2 = Asl,com/(b*d)*(fs2/fc) = 0.88736994
v = Asl,mid/(b*d)*(fsv/fc) = 1.93773
and confined core properties:
b = 90.00
d = 227.00
d' = 13.00
fcc (5A.2, TBDY) = 20.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.67441
2 = Asl,com/(b*d)*(fs2/fc) = 1.67441
v = Asl,mid/(b*d)*(fsv/fc) = 3.65636
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) = 0.69203654
MRc (4.18) = 1.9359E+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) = 0.73305448
MRo (4.18) = 1.3270E+008
MRo < 0.8*MRc

```

--->

$u = cu$ (unconfined full section) = 1.9679130E-005

$\mu = MRc$

Calculation of ratio l_b/l_d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 206387.155$

Calculation of Shear Strength at edge 1, $V_{r1} = 206387.155$

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

$V_{Col0} = 206387.155$

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

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

= 1 (normal-weight concrete)

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

$M/Vd = 2.00$

$\mu_u = 1446.319$

$V_u = 5.7446150E-009$

$d = 0.8 \cdot h = 240.00$

$N_u = 1.0007E+006$

$A_g = 45000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

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

$d = 120.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 190.00$

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

$s/d = 1.58333$

$V_{s2} = 73486.813$ is calculated for section flange, with:

$d = 240.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 190.00$

V_{s2} is multiplied by $Col2 = 0.83333333$

$s/d = 0.79166667$

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

From (11-11), ACI 440: $V_s + V_f \leq 106950.853$

$b_w = 150.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 206387.155$

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

$V_{Col0} = 206387.155$

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

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

= 1 (normal-weight concrete)

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

$M/Vd = 2.00$

$\mu_u = 0.02042443$

$V_u = 5.7446150E-009$

$d = 0.8 \cdot h = 240.00$

$N_u = 1.0007E+006$

$A_g = 45000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

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

$d = 120.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 190.00$

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

$s/d = 1.58333$

$V_{s2} = 73486.813$ is calculated for section flange, with:

$d = 240.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 190.00$

V_{s2} is multiplied by $Col2 = 0.833333333$

$s/d = 0.791666667$

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

From (11-11), ACI 440: $V_s + V_f \leq 106950.853$

$bw = 150.00$

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1
At local axis: 2
Integration Section: (b)
Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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, $f_c = f_{cm} = 20.00$

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 300.00$

Min Height, $H_{min} = 150.00$

Max Width, $W_{max} = 300.00$

Min Width, $W_{min} = 150.00$

Eccentricity, $Ecc = 75.00$

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, $M = -11424.291$

Shear Force, $V_2 = 33296.807$

Shear Force, $V_3 = -8.14666$

Axial Force, $F = -998863.21$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{s,ten} = 2261.947$

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

-Middle: $A_{s,mid} = 2060.885$

Mean Diameter of Tension Reinforcement, $D_bL = 17.77778$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.00535885$

$u = y + p = 0.00630453$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00630453$ ((4.29), Biskinis Phd)

$M_y = 9.2090E+007$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1402.328

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 6.8279E+012$

factor = 0.70

$A_g = 67500.00$

$f_c' = 20.00$

$N = 998863.21$

$E_c * I_g = 9.7541E+012$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$y_{ten} = 2.6076319E-005$

with $f_y = 444.44$

$d = 257.00$

$y = 0.66840824$

$A = 0.19195011$

$B = 0.1517777$

with $pt = 0.00404182$

$pc = 0.02151441$

$pv = 0.05346005$

$N = 998863.21$

$b = 150.00$

" = 0.16731518

$y_{comp} = 7.4754157E-006$

with $f_c = 20.00$

$E_c = 21019.039$

$y = 0.89149964$

$A = 0.05800829$

$B = 0.09347771$

with $E_s = 200000.00$

Calculation of ratio l_b/d

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

- Calculation of p -

From table 10-8: $p = 0.00$

with:

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

shear control ratio $V_y E / C_o I_o E = 1.14818$

$d = 257.00$

$s = 150.00$

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_f / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_f / f_s) = 0.00404182$

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

$L_{stir} = 660.00$, 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.

$NUD = 998863.21$

$A_g = 67500.00$

$f_{cE} = 20.00$

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

$\rho_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.13365012$

$b = 150.00$

$d = 257.00$

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 7

column C1, Floor 1

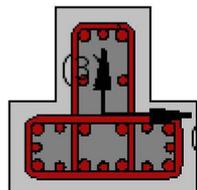
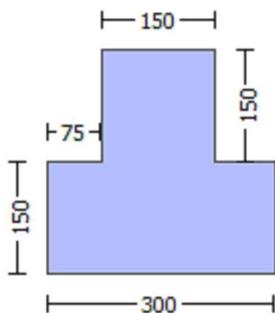
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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, $f_c = f_{c_lower_bound} = 16.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of μ 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, $f_c = f_{cm} = 20.00$
 Existing material: Steel Strength, $f_s = f_{sm} = 444.44$
 #####
 Max Height, $H_{max} = 300.00$
 Min Height, $H_{min} = 150.00$
 Max Width, $W_{max} = 300.00$
 Min Width, $W_{min} = 150.00$
 Eccentricity, $Ecc = 75.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{ou,min} = l_b/l_d \geq 1$)
 No FRP Wrapping

 Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = -8.6087E+006$
 Shear Force, $V_a = 8.14666$
 EDGE -B-
 Bending Moment, $M_b = -11424.291$
 Shear Force, $V_b = -8.14666$
 BOTH EDGES
 Axial Force, $F = -998863.21$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{st} = 0.00$
 -Compression: $A_{sc} = 5152.212$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{s,ten} = 2261.947$
 -Compression: $A_{s,com} = 829.3805$
 -Middle: $A_{s,mid} = 2060.885$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.77778$

 Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 109333.59$
 V_n ((10.3), ASCE 41-17) = $k_n l V_{CoI} = 128627.753$
 $V_{CoI} = 128627.753$
 $k_n l = 1.00$
 displacement_ductility_demand = 0.0351187

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)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 11424.291$
 $V_u = 8.14666$
 $d = 0.8 \cdot h = 240.00$

$Nu = 998863.21$
 $Ag = 45000.00$
 From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 66138.793$
 where:
 $Vs1 = 66138.793$ is calculated for section web, with:
 $d = 240.00$
 $Av = 157079.633$
 $fy = 400.00$
 $s = 190.00$
 $Vs1$ is multiplied by $Col1 = 0.83333333$
 $s/d = 0.79166667$
 $Vs2 = 0.00$ is calculated for section flange, with:
 $d = 120.00$
 $Av = 157079.633$
 $fy = 400.00$
 $s = 190.00$
 $Vs2$ is multiplied by $Col2 = 0.00$
 $s/d = 1.58333$
 $Vf ((11-3)-(11.4), ACI 440) = 0.00$
 From (11-11), ACI 440: $Vs + Vf \leq 95659.751$
 $bw = 150.00$

displacement ductility demand is calculated as ϕ / y

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

From analysis, chord rotation $\theta = 0.00022141$
 $y = (My * Ls / 3) / Eleff = 0.00630453 ((4.29), Biskinis Phd)$
 $My = 9.2090E+007$
 $Ls = M/V$ (with $Ls > 0.1 * L$ and $Ls < 2 * L$) = 1402.328
 From table 10.5, ASCE 41_17: $Eleff = factor * Ec * I_g = 6.8279E+012$
 $factor = 0.70$
 $Ag = 67500.00$
 $fc' = 20.00$
 $N = 998863.21$
 $Ec * I_g = 9.7541E+012$

Calculation of Yielding Moment My

Calculation of ϕ and My according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 2.6076319E-005$
 with $fy = 444.44$
 $d = 257.00$
 $y = 0.66840824$
 $A = 0.19195011$
 $B = 0.1517777$
 with $pt = 0.05867566$
 $pc = 0.02151441$
 $p_v = 0.05346005$
 $N = 998863.21$
 $b = 150.00$
 $\mu = 0.16731518$
 $y_{comp} = 7.4754157E-006$
 with $fc = 20.00$
 $Ec = 21019.039$
 $y = 0.89149964$
 $A = 0.05800829$
 $B = 0.09347771$
 with $Es = 200000.00$

Calculation of ratio l_b/d

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

End Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (b)

Calculation No. 8

column C1, Floor 1

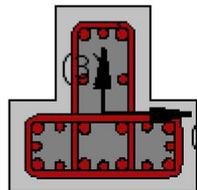
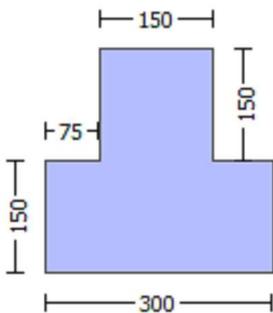
Limit State: Operational Level (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\phi = 0.85$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height, Hmax = 300.00
Min Height, Hmin = 150.00
Max Width, Wmax = 300.00
Min Width, Wmin = 150.00
Eccentricity, Ecc = 75.00
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 ($l_o/l_{o,min} \geq 1$)
No FRP Wrapping

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, Va = -1.1623543E-006
EDGE -B-
Shear Force, Vb = 1.1623543E-006
BOTH EDGES
Axial Force, F = -1.0007E+006
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 5152.212
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 2261.947
-Compression: Asl,com = 829.3805
-Middle: Asl,mid = 2060.885

Calculation of Shear Capacity ratio , $V_e/V_r = 1.14818$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 160672.713$
with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 2.4101E+008$
 $\mu_{u1+} = 1.4763E+008$, 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
 $\mu_{u1-} = 2.4101E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 2.4101E+008$
 $\mu_{u2+} = 1.4763E+008$, 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
 $\mu_{u2-} = 2.4101E+008$, 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:
 $\phi_u = 1.6767311E-005$
 $\mu_u = 1.4763E+008$

with full section properties:

b = 150.00
d = 257.00
d' = 43.00
v = 1.29793
N = 1.0007E+006

$$f_c = 20.00$$

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

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

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 660.00$$

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

$$A_{sec} \text{ (section area)} = 67500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along X)} = 660.00$$

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

$$A_{sec} \text{ (section area)} = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

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

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

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

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

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

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

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

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

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, 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
 $l_o/l_{o,min} = l_b/l_d = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $f_{sv} = f_s = 555.55$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 1.62986$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.59761649$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 1.48499$
 and confined core properties:
 $b = 90.00$
 $d = 227.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 3.07544$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 1.12766$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 2.80207$
 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
 --->
 $cu (4.11) = 0.81221594$
 $M_{Rc} (4.18) = 1.4763E+008$
 --->
 New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
 In expressions below, the following modifications have been made
 - b, d, d' replaced by geometric parameters of the core: $bo, do, d'o$
 - $N, 1, 2, v$ normalised to $bo*do$, instead of $b*d$
 - - parameters of confined concrete, f_{cc}, cc , used in lieu of f_c, 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) = 0.91366546

M_{Ro} (4.18) = 8.4535E+007

M_{Ro} < 0.8*M_{Rc}

--->

u = cu (unconfined full section) = 1.6767311E-005

Mu = M_{Rc}

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 = 1.8792920E-005

Mu = 2.4101E+008

with full section properties:

b = 300.00

d = 257.00

d' = 43.00

v = 0.64896668

N = 1.0007E+006

f_c = 20.00

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(((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} = 35100.00 is the 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} = 16650.00 is the unconfined core area which is equal to bi²/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00404182

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

psh,x ((5.4d), TBDY) = L_{stir}*A_{stir}/(A_{sec}*s) = 0.00404182

L_{stir} (Length of stirrups along Y) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

psh,y ((5.4d), TBDY) = L_{stir}*A_{stir}/(A_{sec}*s) = 0.00404182

L_{stir} (Length of stirrups along X) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

s = 190.00

f_{ywe} = 555.55

f_{ce} = 20.00

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

c = confinement factor = 1.00

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

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

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

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

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

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

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

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

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

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.

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

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.29880825$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.81493158$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.74249322$$

and confined core properties:

$$b = 240.00$$

$$d = 227.00$$

$$d' = 13.00$$

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

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

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.4228729$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 1.15329$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 1.05078$$

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) = 0.45266836

M_{Rc} (4.17) = 2.7366E+008

---->

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

In expressions below, the following modifications have been made

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

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

- f_c, c_c parameters of confined concrete, f_{cc}, c_c used in lieu of f_c, 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) = 0.46882405

M_{Ro} (4.18) = 2.4101E+008

---->

$u = c_u$ (4.2) = 1.8792920E-005

$\mu_u = M_{Ro}$

Calculation of ratio l_b/d

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

Calculation of μ_{u2+}

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

$u = 1.6767311E-005$

$\mu_u = 1.4763E+008$

with full section properties:

$b = 150.00$

$d = 257.00$

$d' = 43.00$

$v = 1.29793$

$N = 1.0007E+006$

$f_c = 20.00$

c_o (5A.5, TBDY) = 0.002

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

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

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

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$

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)

 $p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along Y) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

 $p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along X) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

 $s = 190.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

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

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

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

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

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

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

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

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

with $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

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

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

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

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

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

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

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$suv = 0.032$

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) = 1.62986
2 = Asl,com/(b*d)*(fs2/fc) = 0.59761649
v = Asl,mid/(b*d)*(fsv/fc) = 1.48499
and confined core properties:
b = 90.00
d = 227.00
d' = 13.00
fcc (5A.2, TBDY) = 20.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 3.07544
2 = Asl,com/(b*d)*(fs2/fc) = 1.12766
v = Asl,mid/(b*d)*(fsv/fc) = 2.80207
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) = 0.81221594
MRc (4.18) = 1.4763E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
*cu (4.11) = 0.91366546
MRo (4.18) = 8.4535E+007
MRo < 0.8*MRc
---->
u = cu (unconfined full section) = 1.6767311E-005
Mu = MRc

```

Calculation of ratio l_b/d

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

Calculation of μ_2

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

$$\mu = 1.8792920E-005$$

$$\mu_2 = 2.4101E+008$$

with full section properties:

$$b = 300.00$$

$$d = 257.00$$

$$d' = 43.00$$

$$v = 0.64896668$$

$$N = 1.0007E+006$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu_2: \mu_2^* = \text{shear_factor} * \text{Max}(\mu_2, c_c) = 0.0035$$

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

$$\text{From (5.4b), TBDY: } \mu_2 = 0.0035$$

$$\mu_2 \text{ (5.4c)} = 0.00$$

$$\mu_2^* = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$\mu_2^*,min = \text{Min}(\mu_2^*,x, \mu_2^*,y) = 0.00404182$$

Expression ((5.4d), TBDY) for μ_2^*,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\mu_2^*,x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 660.00$$

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

$$A_{sec} \text{ (section area)} = 67500.00$$

$$\mu_2^*,y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along X)} = 660.00$$

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

$$A_{sec} \text{ (section area)} = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

$$s_u1 = 0.4 * e_{s1_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s1_nominal} = 0.08$,

For calculation of $e_{s1_nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $f_{sy1} = f_s/1.2$, 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.

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

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

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$s_u2 = 0.032$$

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

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

$$s_u2 = 0.4 * e_{s2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s2_nominal} = 0.08$,

For calculation of $e_{s2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $f_{sy2} = f_s/1.2$, from table 5.1, TBDY.

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

$$\text{with } f_{s2} = f_s = 555.55$$

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

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

$$fy_v = 555.55$$

$$s_{uv} = 0.032$$

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

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

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

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

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

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

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

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.29880825$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.81493158$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.74249322$$

and confined core properties:

$$b = 240.00$$

$$d = 227.00$$

$$d' = 13.00$$

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

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

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.4228729$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 1.15329$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 1.05078$$

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) = 0.45266836
MRc (4.17) = 2.7366E+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) = 0.46882405
MRo (4.18) = 2.4101E+008

---->

u = cu (4.2) = 1.8792920E-005
Mu = MRo

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 139936.984

Calculation of Shear Strength at edge 1, Vr1 = 139936.984

Vr1 = VCol ((10.3), ASCE 41-17) = knl*VCol0

VCol0 = 139936.984

knl = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)
fc' = 20.00, but $fc^{0.5} <= 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 934188.794

Vu = 1.1623543E-006

d = 0.8*h = 240.00

Nu = 1.0007E+006

Ag = 45000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 73486.813

where:

Vs1 = 73486.813 is calculated for section web, with:

d = 240.00

Av = 157079.633

fy = 444.44

s = 190.00

Vs1 is multiplied by Col1 = 0.83333333

s/d = 0.79166667

Vs2 = 0.00 is calculated for section flange, with:

d = 120.00

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 190.00$$

Vs2 is multiplied by Col2 = 0.00

$$s/d = 1.58333$$

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

From (11-11), ACI 440: $V_s + V_f \leq 106950.853$

$$b_w = 150.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 139936.984$

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

$$V_{Col0} = 139936.984$$

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

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

= 1 (normal-weight concrete)

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

$$M/Vd = 4.00$$

$$M_u = 760.756$$

$$V_u = 1.1623543E+006$$

$$d = 0.8 * h = 240.00$$

$$N_u = 1.0007E+006$$

$$A_g = 45000.00$$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

$V_{s1} = 73486.813$ is calculated for section web, with:

$$d = 240.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 190.00$$

Vs1 is multiplied by Col1 = 0.83333333

$$s/d = 0.79166667$$

Vs2 = 0.00 is calculated for section flange, with:

$$d = 120.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 190.00$$

Vs2 is multiplied by Col2 = 0.00

$$s/d = 1.58333$$

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

From (11-11), ACI 440: $V_s + V_f \leq 106950.853$

$$b_w = 150.00$$

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\phi = 0.85$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

#####

Max Height, $H_{max} = 300.00$

Min Height, $H_{min} = 150.00$

Max Width, $W_{max} = 300.00$

Min Width, $W_{min} = 150.00$

Eccentricity, $Ecc = 75.00$

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, $V_a = -5.7446150E-009$

EDGE -B-

Shear Force, $V_b = 5.7446150E-009$

BOTH EDGES

Axial Force, $F = -1.0007E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1231.504$

-Compression: $As_{c,com} = 1231.504$

-Middle: $As_{mid} = 2689.203$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.62533189$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 129060.47$

with

$M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 1.9359E+008$

$Mu_{1+} = 1.9359E+008$, 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

$Mu_{1-} = 1.9359E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 1.9359E+008$

$Mu_{2+} = 1.9359E+008$, 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

$Mu_{2-} = 1.9359E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment
direction which is defined for the the static loading combination

Calculation of Mu_{1+}

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

$\phi_u = 1.9679130E-005$

$Mu = 1.9359E+008$

with full section properties:

b = 150.00
d = 257.00
d' = 43.00
v = 1.29793
N = 1.0007E+006

fc = 20.00
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

wc (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 = 35100.00 is the 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 = 16650.00 is the unconfined core area which is equal to bi²/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00404182

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) = 0.00404182

Lstir (Length of stirrups along Y) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00404182

Lstir (Length of stirrups along X) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

s = 190.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

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

lo/lou,min = lb/d = 1.00

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

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

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

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^{2/3}), from 10.3.5, 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

$su_2 = 0.4 * esu_2_nominal ((5.5), TBDY) = 0.032$
 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 $Es_2 = Es = 200000.00$
 $yv = 0.00231479$
 $shv = 0.008$
 $ftv = 666.66$
 $fyv = 555.55$
 $suv = 0.032$
 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.
 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 $Es_v = Es = 200000.00$
 $1 = Asl, ten / (b * d) * (fs_1 / fc) = 0.88736994$
 $2 = Asl, com / (b * d) * (fs_2 / fc) = 0.88736994$
 $v = Asl, mid / (b * d) * (fsv / fc) = 1.93773$
 and confined core properties:
 $b = 90.00$
 $d = 227.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = Asl, ten / (b * d) * (fs_1 / fc) = 1.67441$
 $2 = Asl, com / (b * d) * (fs_2 / fc) = 1.67441$
 $v = Asl, mid / (b * d) * (fsv / fc) = 3.65636$
 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)
 --->
 $v < s, y_1$ - LHS eq.(4.7) is not satisfied
 --->
 $v < v_{c, y_1}$ - RHS eq.(4.6) is not satisfied
 --->
 $cu (4.11) = 0.69203654$
 $MRC (4.18) = 1.9359E+008$
 --->
 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
 --->
 $v^* < v^* s, y_2$ - LHS eq.(4.5) is not satisfied
 --->
 $v^* < v^* s, c$ - LHS eq.(4.5) is not satisfied
 --->
 Subcase rejected

--->

New Subcase: Failure of compression zone

--->

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

--->

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

--->

*cu (4.11) = 0.73305448

MRO (4.18) = 1.3270E+008

MRO < 0.8*MRc

--->

u = cu (unconfined full section) = 1.9679130E-005

Mu = MRc

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Mu1-

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

u = 1.9679130E-005

Mu = 1.9359E+008

with full section properties:

b = 150.00

d = 257.00

d' = 43.00

v = 1.29793

N = 1.0007E+006

fc = 20.00

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 = $\text{Max}(((Aconf,max - AnoConf)/Aconf,max) * (Aconf,min/Aconf,max), 0) = 0.00$

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 = 35100.00 is the 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 = 16650.00 is the unconfined core area which is equal to $bi^2/6$ as defined at (A.2).

psh,min = $\text{Min}(psh,x, psh,y) = 0.00404182$

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) = $Lstir * Astir / (Asec * s) = 0.00404182$

Lstir (Length of stirrups along Y) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

psh,y ((5.4d), TBDY) = $Lstir * Astir / (Asec * s) = 0.00404182$

Lstir (Length of stirrups along X) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

$s = 190.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$
 From ((5.A.5), TBDY), TBDY: $cc = 0.002$
 $c = \text{confinement factor} = 1.00$
 $y_1 = 0.00231479$
 $sh_1 = 0.008$
 $ft_1 = 666.66$
 $fy_1 = 555.55$
 $su_1 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 1.00$
 $su_1 = 0.4 * esu_1 \text{ nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu_1 \text{ nominal} = 0.08$,
 For calculation of $esu_1 \text{ nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_1 = fs = 555.55$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.00231479$
 $sh_2 = 0.008$
 $ft_2 = 666.66$
 $fy_2 = 555.55$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/lb, \min = 1.00$
 $su_2 = 0.4 * esu_2 \text{ nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu_2 \text{ nominal} = 0.08$,
 For calculation of $esu_2 \text{ nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_2 = fs = 555.55$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.00231479$
 $sh_v = 0.008$
 $ft_v = 666.66$
 $fy_v = 555.55$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 1.00$
 $suv = 0.4 * esuv \text{ nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esuv \text{ nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv \text{ nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = fs = 555.55$
 with $Esv = Es = 200000.00$
 $1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.88736994$
 $2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.88736994$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 1.93773$
 and confined core properties:
 $b = 90.00$
 $d = 227.00$
 $d' = 13.00$
 $f_{cc} (5A.2, \text{TBDY}) = 20.00$
 $cc (5A.5, \text{TBDY}) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 1.67441$
 $2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 1.67441$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 3.65636$

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)

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

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

---->
 ϵ_{cu} (4.11) = 0.69203654
 M_{Rc} (4.18) = 1.9359E+008

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

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o
- $N, \epsilon_1, \epsilon_2, v$ normalised to $b_o d_o$, instead of $b d$
- $\epsilon_c, \epsilon_{cc}$ - 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

---->
 ϵ^*_{cu} (4.11) = 0.73305448
 M_{Ro} (4.18) = 1.3270E+008

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

---->
 $\epsilon_u = \epsilon_{cu}$ (unconfined full section) = 1.9679130E-005
 $\mu_u = M_{Rc}$

Calculation of ratio l_b/d

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

Calculation of μ_{u2+}

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

$\epsilon_u = 1.9679130E-005$

$\mu_u = 1.9359E+008$

with full section properties:

$b = 150.00$

$d = 257.00$

$d' = 43.00$

$v = 1.29793$

$N = 1.0007E+006$

$f_c = 20.00$

ϵ_{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

$ase = \text{Max}(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.00$

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.

$Aconf,max = 35100.00$ is the 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.

$AnoConf = 16650.00$ is the unconfined core area which is equal to $bi^2/6$ as defined at (A.2).

$psh,min = \text{Min}(psh,x, psh,y) = 0.00404182$

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) = $Lstir * Astir / (Asec * s) = 0.00404182$

$Lstir$ (Length of stirrups along Y) = 660.00

$Astir$ (stirrups area) = 78.53982

$Asec$ (section area) = 67500.00

 psh,y ((5.4d), TBDY) = $Lstir * Astir / (Asec * s) = 0.00404182$

$Lstir$ (Length of stirrups along X) = 660.00

$Astir$ (stirrups area) = 78.53982

$Asec$ (section area) = 67500.00

 $s = 190.00$

$fywe = 555.55$

$fce = 20.00$

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

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

$y1 = 0.00231479$

$sh1 = 0.008$

$ft1 = 666.66$

$fy1 = 555.55$

$su1 = 0.032$

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

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

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

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

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

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

with $fs2 = fs = 555.55$

with $Es2 = Es = 200000.00$

$yv = 0.00231479$
 $shv = 0.008$
 $ftv = 666.66$
 $fyv = 555.55$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 1.00$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv,ftv,fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1,ft1,fy1$, are also multiplied by $Min(1,1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = fs = 555.55$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.88736994$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.88736994$
 $v = Asl,mid/(b*d)*(fsv/fc) = 1.93773$
 and confined core properties:
 $b = 90.00$
 $d = 227.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c =$ confinement factor $= 1.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 1.67441$
 $2 = Asl,com/(b*d)*(fs2/fc) = 1.67441$
 $v = Asl,mid/(b*d)*(fsv/fc) = 3.65636$
 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
 --->
 $cu (4.11) = 0.69203654$
 $MRC (4.18) = 1.9359E+008$
 --->
 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) = 0.73305448
MRo (4.18) = 1.3270E+008
MRo < 0.8*MRc

--->
u = cu (unconfined full section) = 1.9679130E-005
Mu = MRc

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

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

u = 1.9679130E-005
Mu = 1.9359E+008

with full section properties:

b = 150.00
d = 257.00
d' = 43.00
v = 1.29793
N = 1.0007E+006
fc = 20.00
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 = 35100.00 is the 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 = 16650.00 is the unconfined core area which is equal to bi²/6 as defined at (A.2).

psh,min = Min(psh,x, psh,y) = 0.00404182

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) = 0.00404182

Lstir (Length of stirrups along Y) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00404182

Lstir (Length of stirrups along X) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

s = 190.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

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

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

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

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

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

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

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

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

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.

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

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.88736994$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.88736994$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 1.93773$$

and confined core properties:

$$b = 90.00$$

$$d = 227.00$$

$$d' = 13.00$$

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

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

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 1.67441$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 1.67441$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 3.65636$$

Case/Assumption: Unconfined full section - Steel rupture

' does not satisfy Eq. (4.3)

--->

v < vs,c - RHS eq.(4.5) is not satisfied

--->

Case/Assumption Rejected.

--->

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

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

cu (4.11) = 0.69203654
MRc (4.18) = 1.9359E+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) = 0.73305448
MRo (4.18) = 1.3270E+008
MRo < 0.8*MRc

---->
u = cu (unconfined full section) = 1.9679130E-005
Mu = MRc

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Shear Strength Vr = Min(Vr1, Vr2) = 206387.155

Calculation of Shear Strength at edge 1, Vr1 = 206387.155
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VCol0
VCol0 = 206387.155
knl = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)
fc' = 20.00, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
M/Vd = 2.00
Mu = 1446.319
Vu = 5.7446150E-009
d = 0.8*h = 240.00
Nu = 1.0007E+006
Ag = 45000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 73486.813
where:
Vs1 = 0.00 is calculated for section web, with:
d = 120.00

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 190.00$$

Vs1 is multiplied by Col1 = 0.00

$$s/d = 1.58333$$

Vs2 = 73486.813 is calculated for section flange, with:

$$d = 240.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 190.00$$

Vs2 is multiplied by Col2 = 0.83333333

$$s/d = 0.79166667$$

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

From (11-11), ACI 440: $V_s + V_f \leq 106950.853$

$$b_w = 150.00$$

Calculation of Shear Strength at edge 2, $V_r2 = 206387.155$

$V_r2 = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l * V_{Col0}$

$$V_{Col0} = 206387.155$$

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

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

= 1 (normal-weight concrete)

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

$$M/Vd = 2.00$$

$$\mu_u = 0.02042443$$

$$V_u = 5.7446150E-009$$

$$d = 0.8 * h = 240.00$$

$$N_u = 1.0007E+006$$

$$A_g = 45000.00$$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

Vs1 = 0.00 is calculated for section web, with:

$$d = 120.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 190.00$$

Vs1 is multiplied by Col1 = 0.00

$$s/d = 1.58333$$

Vs2 = 73486.813 is calculated for section flange, with:

$$d = 240.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 190.00$$

Vs2 is multiplied by Col2 = 0.83333333

$$s/d = 0.79166667$$

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

From (11-11), ACI 440: $V_s + V_f \leq 106950.853$

$$b_w = 150.00$$

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\phi = 0.85$
 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, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 Max Height, $H_{max} = 300.00$
 Min Height, $H_{min} = 150.00$
 Max Width, $W_{max} = 300.00$
 Min Width, $W_{min} = 150.00$
 Eccentricity, $Ecc = 75.00$
 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, $M = -6.6728E+006$
 Shear Force, $V_2 = 33296.807$
 Shear Force, $V_3 = -8.14666$
 Axial Force, $F = -998863.21$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{st} = 0.00$
 -Compression: $A_{sc} = 5152.212$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{st,ten} = 1231.504$
 -Compression: $A_{sc,com} = 1231.504$
 -Middle: $A_{sc,mid} = 2689.203$
 Mean Diameter of Tension Reinforcement, $DbL = 17.60$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \phi \cdot u = 0.00167879$
 $u = y + p = 0.00197505$

- Calculation of y -

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00197505$ ((4.29), Biskinis Phd)
 $M_y = 1.1034E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00
 From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 5.5865E+012$
 factor = 0.70
 $A_g = 67500.00$
 $f_c' = 20.00$
 $N = 998863.21$
 $E_c \cdot I_g = 7.9807E+012$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 2.2096501E-005$
 with $f_y = 444.44$

d = 257.00
 y = 0.60868498
 A = 0.19195011
 B = 0.1363059
 with pt = 0.00404182
 pc = 0.03194564
 pv = 0.06975884
 N = 998863.21
 b = 150.00
 " = 0.16731518
 y_comp = 8.4828072E-006
 with fc = 20.00
 Ec = 21019.039
 y = 0.78562795
 A = 0.05800829
 B = 0.0780059
 with Es = 200000.00

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

- Calculation of p -

From table 10-8: p = 0.00

with:

- Columns not controlled by inadequate development or splicing along the clear height because lb/d >= 1

shear control ratio $V_y E / V_{col} O E = 0.62533189$

d = 257.00

s = 150.00

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00404182$

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

$L_{stir} = 660.00$, 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 = 998863.21

$A_g = 67500.00$

$f_{cE} = 20.00$

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

$p_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.13365012$

b = 150.00

d = 257.00

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (b)

Calculation No. 9

column C1, Floor 1

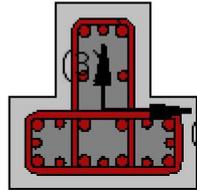
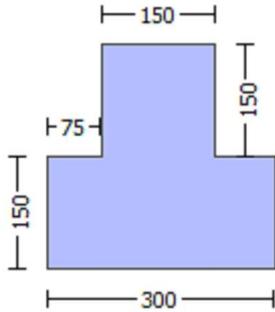
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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, $f_c = f_{c_lower_bound} = 16.00$

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

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

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

#####

Max Height, $H_{max} = 300.00$

Min Height, $H_{min} = 150.00$

Max Width, $W_{max} = 300.00$

Min Width, $W_{min} = 150.00$

Eccentricity, $Ecc = 75.00$

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 ($l_o/l_{o,min} = l_b/d \geq 1$)

No FRP Wrapping

Stepwise Properties

EDGE -A-
Bending Moment, Ma = -2.9481E+008
Shear Force, Va = -38091.238
EDGE -B-
Bending Moment, Mb = -7.6430E+006
Shear Force, Vb = 38091.238
BOTH EDGES
Axial Force, F = -997748.352
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 2375.044
-Compression: Aslc = 2777.168
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 1231.504
-Compression: Asl,com = 1231.504
-Middle: Asl,mid = 2689.203
Mean Diameter of Tension Reinforcement, DbL,ten = 17.60

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity VR = $\phi V_n = 109306.383$
Vn ((10.3), ASCE 41-17) = knl*VColO = 128595.745
VCol = 128595.745
knl = 1.00
displacement_ductility_demand = 1.58915

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

= 1 (normal-weight concrete)
fc' = 16.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 2.9481E+008
Vu = 38091.238
d = 0.8*h = 240.00
Nu = 997748.352
Ag = 45000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 66138.793
where:
Vs1 = 0.00 is calculated for section web, with:
d = 120.00
Av = 157079.633
fy = 400.00
s = 190.00
Vs1 is multiplied by Col1 = 0.00
s/d = 1.58333
Vs2 = 66138.793 is calculated for section flange, with:
d = 240.00
Av = 157079.633
fy = 400.00
s = 190.00
Vs2 is multiplied by Col2 = 0.83333333
s/d = 0.79166667
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 95659.751
bw = 150.00

displacement_ductility_demand is calculated as ϕ / y

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

From analysis, chord rotation = 0.06279247
 $y = (M_y * L_s / 3) / E_{eff} = 0.03951321$ ((4.29), Biskinis Phd)

My = 1.1037E+008
Ls = M/V (with Ls > 0.1*L and Ls < 2*L) = 6000.00
From table 10.5, ASCE 41_17: Eleff = factor*Ec*Ig = 5.5865E+012
factor = 0.70
Ag = 67500.00
fc' = 20.00
N = 997748.352
Ec*Ig = 7.9807E+012

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

y = Min(y_ten, y_com)
y_ten = 2.2090882E-005
with fy = 444.44
d = 257.00
y = 0.60858546
A = 0.19188504
B = 0.13624083
with pt = 0.03194564
pc = 0.03194564
pv = 0.06975884
N = 997748.352
b = 150.00
" = 0.16731518
y_comp = 8.4879027E-006
with fc = 20.00
Ec = 21019.039
y = 0.78515631
A = 0.05809272
B = 0.0780059
with Es = 200000.00

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

End Of Calculation of Shear Capacity for element: column TC1 of floor 1
At local axis: 2
Integration Section: (a)

Calculation No. 10

column C1, Floor 1

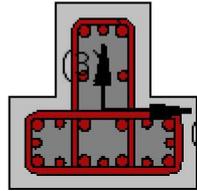
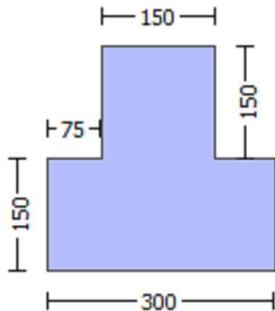
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_u)

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height, $H_{max} = 300.00$

Min Height, $H_{min} = 150.00$

Max Width, $W_{max} = 300.00$

Min Width, $W_{min} = 150.00$

Eccentricity, $E_{cc} = 75.00$

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, $V_a = -1.1623543E-006$

EDGE -B-

Shear Force, $V_b = 1.1623543E-006$

BOTH EDGES

Axial Force, $F = -1.0007E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{st,ten} = 2261.947$

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

-Middle: $A_{sl,mid} = 2060.885$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.14818$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 160672.713$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.4101E+008$

$M_{u1+} = 1.4763E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.4101E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.4101E+008$

$M_{u2+} = 1.4763E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 2.4101E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of M_{u1+}

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

$\phi_u = 1.6767311E-005$

$M_u = 1.4763E+008$

with full section properties:

$b = 150.00$

$d = 257.00$

$d' = 43.00$

$v = 1.29793$

$N = 1.0007E+006$

$f_c = 20.00$

$\alpha = 0.002$ (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: $\phi_u = 0.0035$

$\phi_{ue} = 0.00$

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

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b^2/6$ as defined at (A.2).

$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00404182$

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)

$$\text{psh,x ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * \text{s}) = 0.00404182$$

$$\text{Lstir (Length of stirrups along Y)} = 660.00$$

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

$$\text{Asec (section area)} = 67500.00$$

$$\text{psh,y ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * \text{s}) = 0.00404182$$

$$\text{Lstir (Length of stirrups along X)} = 660.00$$

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

$$\text{Asec (section area)} = 67500.00$$

$$\text{s} = 190.00$$

$$\text{fywe} = 555.55$$

$$\text{fce} = 20.00$$

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

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

$$\text{y1} = 0.00231479$$

$$\text{sh1} = 0.008$$

$$\text{ft1} = 666.66$$

$$\text{fy1} = 555.55$$

$$\text{su1} = 0.032$$

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

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

$$\text{su1} = 0.4 * \text{esu1_nominal ((5.5), TBDY)} = 0.032$$

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

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

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

$$\text{lo/lou,min} = \text{lb/lb,min} = 1.00$$

$$\text{su2} = 0.4 * \text{esu2_nominal ((5.5), TBDY)} = 0.032$$

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

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

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

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

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

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

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

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

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

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

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

$$1 = \text{Asl,ten} / (\text{b} * \text{d}) * (\text{fs1} / \text{fc}) = 1.62986$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.59761649$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 1.48499$$

and confined core properties:

$$b = 90.00$$

$$d = 227.00$$

$$d' = 13.00$$

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

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

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 3.07544$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 1.12766$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 2.80207$$

Case/Assumption: Unconfined full section - Steel rupture

' does not satisfy Eq. (4.3)

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

Case/Assumption Rejected.

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

' satisfies Eq. (4.4)

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

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

$$c_u (4.11) = 0.81221594$$

$$M_{Rc} (4.18) = 1.4763E+008$$

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

In expressions below, the following modifications have been made

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

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

- f_{cc} , c_c parameters of confined concrete, f_{cc} , c_c , used in lieu of f_c , 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

$$*c_u (4.11) = 0.91366546$$

$$M_{Ro} (4.18) = 8.4535E+007$$

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

$$u = c_u (\text{unconfined full section}) = 1.6767311E-005$$

$$M_u = M_{Rc}$$

Calculation of ratio l_b/l_d

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

Calculation of M_{u1} -

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

$$\mu = 1.8792920E-005$$

$$M_u = 2.4101E+008$$

with full section properties:

$$b = 300.00$$

$$d = 257.00$$

$$d' = 43.00$$

$$v = 0.64896668$$

$$N = 1.0007E+006$$

$$f_c = 20.00$$

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

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

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

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

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

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

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00404182$$

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

$$\phi_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 660.00$$

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

$$A_{sec} \text{ (section area)} = 67500.00$$

$$\phi_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along X)} = 660.00$$

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

$$A_{sec} \text{ (section area)} = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

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

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

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

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$, from 10.3.5, 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/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) = 0.29880825
2 = Asl,com/(b*d)*(fs2/fc) = 0.81493158
v = Asl,mid/(b*d)*(fsv/fc) = 0.74249322
and confined core properties:
b = 240.00
d = 227.00
d' = 13.00
fcc (5A.2, TBDY) = 20.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.4228729
2 = Asl,com/(b*d)*(fs2/fc) = 1.15329
v = Asl,mid/(b*d)*(fsv/fc) = 1.05078
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) = 0.45266836
MRc (4.17) = 2.7366E+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) = 0.46882405

MRo (4.18) = 2.4101E+008

--->

u = cu (4.2) = 1.8792920E-005

Mu = MRo

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

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

u = 1.6767311E-005

Mu = 1.4763E+008

with full section properties:

b = 150.00

d = 257.00

d' = 43.00

v = 1.29793

N = 1.0007E+006

fc = 20.00

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 = 35100.00 is the 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 = 16650.00 is the unconfined core area which is equal to bi²/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00404182

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) = 0.00404182

Lstir (Length of stirrups along Y) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00404182

Lstir (Length of stirrups along X) = 660.00
Astir (stirrups area) = 78.53982
Asec (section area) = 67500.00

s = 190.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

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

lo/lou,min = lb/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) = 1.62986

2 = Asl,com/(b*d)*(fs2/fc) = 0.59761649

v = Asl,mid/(b*d)*(fsv/fc) = 1.48499

and confined core properties:

b = 90.00

d = 227.00

d' = 13.00

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00
1 = $Asl,ten/(b*d)*(fs1/fc) = 3.07544$
2 = $Asl,com/(b*d)*(fs2/fc) = 1.12766$
v = $Asl,mid/(b*d)*(fsv/fc) = 2.80207$

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) = 0.81221594
MRc (4.18) = 1.4763E+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) = 0.91366546
MRo (4.18) = 8.4535E+007

MRo < 0.8*MRc

---->
u = cu (unconfined full section) = 1.6767311E-005
Mu = MRc

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.8792920E-005
Mu = 2.4101E+008

with full section properties:
b = 300.00
d = 257.00
d' = 43.00

$$v = 0.64896668$$

$$N = 1.0007E+006$$

$$f_c = 20.00$$

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

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

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

$$\text{From (5.4b), TBDY: } c_u = 0.0035$$

$$w_e (5.4c) = 0.00$$

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

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., 10.11061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} (\text{Length of stirrups along } Y) = 660.00$$

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

$$A_{sec} (\text{section area}) = 67500.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} (\text{Length of stirrups along } X) = 660.00$$

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

$$A_{sec} (\text{section area}) = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

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

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

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

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

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

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

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

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

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

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

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

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

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

For calculation of $esu_2_{nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered

characteristic value $f_{s2} = f_s/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, 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 $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY

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

characteristic value $f_{sv} = f_{sv}/1.2$, 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 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.29880825$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.81493158$

$v = Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.74249322$

and confined core properties:

$b = 240.00$

$d = 227.00$

$d' = 13.00$

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

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

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

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.4228729$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 1.15329$

$v = Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 1.05078$

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

$cu (4.10) = 0.45266836$

$M_{Rc} (4.17) = 2.7366E+008$

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

--->

*cu (4.11) = 0.46882405

M_{Ro} (4.18) = 2.4101E+008

--->

u = cu (4.2) = 1.8792920E-005

Mu = M_{Ro}

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 139936.984$

Calculation of Shear Strength at edge 1, $V_{r1} = 139936.984$

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

V_{Col0} = 139936.984

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)

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

M/Vd = 4.00

Mu = 934188.794

Vu = 1.1623543E-006

d = 0.8*h = 240.00

Nu = 1.0007E+006

Ag = 45000.00

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

$V_{s1} = 73486.813$ is calculated for section web, with:

d = 240.00

Av = 157079.633

fy = 444.44

s = 190.00

V_{s1} is multiplied by Col1 = 0.83333333

s/d = 0.79166667

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

d = 120.00

Av = 157079.633

fy = 444.44

s = 190.00

V_{s2} is multiplied by Col2 = 0.00

s/d = 1.58333

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

From (11-11), ACI 440: $V_s + V_f \leq 106950.853$

bw = 150.00

Calculation of Shear Strength at edge 2, $V_{r2} = 139936.984$

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

V_{Col0} = 139936.984

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)

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

$M/Vd = 4.00$
 $\mu_u = 760.756$
 $V_u = 1.1623543E-006$
 $d = 0.8 \cdot h = 240.00$
 $N_u = 1.0007E+006$
 $A_g = 45000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$
 where:
 $V_{s1} = 73486.813$ is calculated for section web, with:
 $d = 240.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 190.00$
 V_{s1} is multiplied by $Col1 = 0.83333333$
 $s/d = 0.79166667$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 120.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 190.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.58333$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
 From (11-11), ACI 440: $V_s + V_f \leq 106950.853$
 $b_w = 150.00$

 End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
 At local axis: 3

 Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rctcs

Constant Properties

 Knowledge Factor, $\phi = 0.85$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$
 #####
 Max Height, $H_{max} = 300.00$
 Min Height, $H_{min} = 150.00$
 Max Width, $W_{max} = 300.00$
 Min Width, $W_{min} = 150.00$
 Eccentricity, $Ecc = 75.00$
 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, $V_a = -5.7446150E-009$

EDGE -B-

Shear Force, $V_b = 5.7446150E-009$

BOTH EDGES

Axial Force, $F = -1.0007E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1231.504$

-Compression: $As_{c,com} = 1231.504$

-Middle: $As_{c,mid} = 2689.203$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.62533189$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 129060.47$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.9359E+008$
 $Mu_{1+} = 1.9359E+008$, 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
 $Mu_{1-} = 1.9359E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.9359E+008$
 $Mu_{2+} = 1.9359E+008$, 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
 $Mu_{2-} = 1.9359E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu_{1+}

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

$\phi_u = 1.9679130E-005$

$Mu = 1.9359E+008$

with full section properties:

$b = 150.00$

$d = 257.00$

$d' = 43.00$

$v = 1.29793$

$N = 1.0007E+006$

$f_c = 20.00$

ω (5A.5, TBDY) = 0.002

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

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

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

ω_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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$

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)

 $p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along Y) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

 $p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along X) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

 $s = 190.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

with $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

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

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

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

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

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

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

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$su_v = 0.032$

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

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

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

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

considering characteristic value $fsy_v = fs_v/1.2$, 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 $\text{Min}(1, 1.25 \cdot (l_b/d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $f_{sv} = f_s = 555.55$

with $E_{sv} = E_s = 200000.00$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.88736994$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.88736994$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 1.93773$

and confined core properties:

$b = 90.00$

$d = 227.00$

$d' = 13.00$

$f_{cc} \text{ (5A.2, TBDY)} = 20.00$

$cc \text{ (5A.5, TBDY)} = 0.002$

$c = \text{confinement factor} = 1.00$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 1.67441$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 1.67441$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 3.65636$

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

--->

$\ast cu \text{ (4.11)} = 0.69203654$

$M_{Rc} \text{ (4.18)} = 1.9359E+008$

--->

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o

- $N, 1, 2, v$ normalised to $b_o \cdot d_o$, instead of $b \cdot d$

- f_{cc}, cc parameters of confined concrete, f_{cc}, cc , used in lieu of f_c, cc

--->

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

--->

$\ast cu \text{ (4.11)} = 0.73305448$

$M_{Ro} \text{ (4.18)} = 1.3270E+008$

$M_{Ro} < 0.8 \cdot M_{Rc}$

--->

$u = cu \text{ (unconfined full section)} = 1.9679130E-005$

$M_u = M_{Rc}$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Mu1-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.9679130E-005$$

$$Mu = 1.9359E+008$$

with full section properties:

$$b = 150.00$$

$$d = 257.00$$

$$d' = 43.00$$

$$v = 1.29793$$

$$N = 1.0007E+006$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0035$$

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 660.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 67500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along X)} = 660.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/d = 1.00$$

$$su_1 = 0.4 * esu_1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu_1_{nominal} = 0.08$,

For calculation of $esu_1_{nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs_1 = fs = 555.55$$

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
 $lo/lo_{min} = lb/lb_{min} = 1.00$
 $su_2 = 0.4 * esu_{2_nominal} ((5.5), TBDY) = 0.032$
 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 $fs_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_2 = fs = 555.55$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00231479$
 $sh_v = 0.008$
 $ft_v = 666.66$
 $fy_v = 555.55$
 $su_v = 0.032$
 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
 $lo/lo_{min} = lb/d = 1.00$
 $su_v = 0.4 * esu_{v_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{v_nominal} = 0.08$,
 considering characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY
 For calculation of $esu_{v_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_v = fs = 555.55$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.88736994$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.88736994$
 $v = A_{sl,mid}/(b*d) * (fs_v/f_c) = 1.93773$
 and confined core properties:
 $b = 90.00$
 $d = 227.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 1.67441$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 1.67441$
 $v = A_{sl,mid}/(b*d) * (fs_v/f_c) = 3.65636$
 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
 --->
 $cu (4.11) = 0.69203654$
 $M_{Rc} (4.18) = 1.9359E+008$
 --->
 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 $b_0 \cdot d_0$, instead of $b \cdot d$
- - parameters of confined concrete, f_{cc} , c_c , used in lieu of f_c , e_{cu}

---->
Subcase: Rupture of tension steel

---->
 $v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->
 $v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

---->
Subcase rejected

---->
New Subcase: Failure of compression zone

---->
 $v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

---->
 $v^* < v^*_{c,y1}$ - RHS eq.(4.6) is not satisfied

---->
 μ_{cu} (4.11) = 0.73305448

M_{Ro} (4.18) = 1.3270E+008

$M_{Ro} < 0.8 \cdot M_{Rc}$

---->
 $\mu = \mu_{cu}$ (unconfined full section) = 1.9679130E-005

$\mu = M_{Rc}$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 1.9679130E-005$

$\mu = 1.9359E+008$

with full section properties:

$b = 150.00$

$d = 257.00$

$d' = 43.00$

$v = 1.29793$

$N = 1.0007E+006$

$f_c = 20.00$

μ_{co} (5A.5, TBDY) = 0.002

Final value of μ_{cu} : $\mu_{cu}^* = \text{shear_factor} \cdot \text{Max}(\mu_{cu}, \mu_{cc}) = 0.0035$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_{cu} = 0.0035$

we (5.4c) = 0.00

$\mu_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.00$

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.00404182$

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)

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00404182$$

$$Lstir (\text{Length of stirrups along Y}) = 660.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 67500.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00404182$$

$$Lstir (\text{Length of stirrups along X}) = 660.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 67500.00$$

$$s = 190.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/ld = 1.00$$

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_nominal = 0.08,$$

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

$$y1, sh1,ft1,fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs1 = fs = 555.55$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00231479$$

$$sh2 = 0.008$$

$$ft2 = 666.66$$

$$fy2 = 555.55$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 1.00$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_nominal = 0.08,$$

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

$$y2, sh2,ft2,fy2, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs2 = fs = 555.55$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00231479$$

$$shv = 0.008$$

$$ftv = 666.66$$

$$fyv = 555.55$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/ld = 1.00$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esuv_nominal = 0.08,$$

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

$$yv, shv,ftv,fyv, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fsv = fs = 555.55$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.88736994$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.88736994$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 1.93773$$

and confined core properties:

$$b = 90.00$$

$$d = 227.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 20.00$$

$$cc (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 1.67441$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 1.67441$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 3.65636$$

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

$$cu (4.11) = 0.69203654$$

$$MRc (4.18) = 1.9359E+008$$

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 , 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

$$*cu (4.11) = 0.73305448$$

$$MRo (4.18) = 1.3270E+008$$

$$MRo < 0.8*MRc$$

$$u = cu (\text{unconfined full section}) = 1.9679130E-005$$

$$Mu = MRc$$

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:

$$u = 1.9679130E-005$$

Mu = 1.9359E+008

with full section properties:

b = 150.00

d = 257.00

d' = 43.00

v = 1.29793

N = 1.0007E+006

fc = 20.00

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 = 35100.00 is the 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 = 16650.00 is the unconfined core area which is equal to bi²/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00404182

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) = 0.00404182

Lstir (Length of stirrups along Y) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00404182

Lstir (Length of stirrups along X) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

s = 190.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^{2/3}), from 10.3.5, 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
 $l_o/l_{o,min} = l_b/l_{b,min} = 1.00$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, 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
 $l_o/l_{o,min} = l_b/l_d = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
with $fsv = fs = 555.55$
with $Es_v = Es = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/fc) = 0.88736994$
 $2 = A_{sl,com}/(b*d) * (fs_2/fc) = 0.88736994$
 $v = A_{sl,mid}/(b*d) * (fsv/fc) = 1.93773$
and confined core properties:
 $b = 90.00$
 $d = 227.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/fc) = 1.67441$
 $2 = A_{sl,com}/(b*d) * (fs_2/fc) = 1.67441$
 $v = A_{sl,mid}/(b*d) * (fsv/fc) = 3.65636$
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
---->
 $cu (4.11) = 0.69203654$
 $M_{Rc} (4.18) = 1.9359E+008$
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: $bo, do, d'o$
- $N, 1, 2, v$ normalised to $bo*do$, instead of $b*d$
- - parameters of confined concrete, f_{cc}, cc , used in lieu of f_c, 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

--->

μ_{cu} (4.11) = 0.73305448

M_{Ro} (4.18) = 1.3270E+008

$M_{Ro} < 0.8 \cdot M_{Rc}$

--->

$\mu = \mu_{cu}$ (unconfined full section) = 1.9679130E-005

$\mu_u = M_{Rc}$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 206387.155$

Calculation of Shear Strength at edge 1, $V_{r1} = 206387.155$

$V_{r1} = V_{Co1}$ ((10.3), ASCE 41-17) = $k_n l \cdot V_{Co10}$

$V_{Co10} = 206387.155$

$k_n l = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f \cdot V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

 $\mu = 1$ (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1446.319$

$V_u = 5.7446150E-009$

$d = 0.8 \cdot h = 240.00$

$N_u = 1.0007E+006$

$A_g = 45000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 120.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 190.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 1.58333$

$V_{s2} = 73486.813$ is calculated for section flange, with:

$d = 240.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 190.00$

V_{s2} is multiplied by $Col2 = 0.833333333$

$s/d = 0.79166667$

V_f ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: $V_s + V_f \leq 106950.853$

$b_w = 150.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 206387.155$

$V_{r2} = V_{Co2}$ ((10.3), ASCE 41-17) = $k_n l \cdot V_{Co20}$

$V_{Co20} = 206387.155$

kn1 = 1 (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

fc' = 20.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 0.02042443

Vu = 5.7446150E-009

d = 0.8*h = 240.00

Nu = 1.0007E+006

Ag = 45000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 73486.813

where:

Vs1 = 0.00 is calculated for section web, with:

d = 120.00

Av = 157079.633

fy = 444.44

s = 190.00

Vs1 is multiplied by Col1 = 0.00

s/d = 1.58333

Vs2 = 73486.813 is calculated for section flange, with:

d = 240.00

Av = 157079.633

fy = 444.44

s = 190.00

Vs2 is multiplied by Col2 = 0.83333333

s/d = 0.79166667

Vf ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: Vs + Vf <= 106950.853

bw = 150.00

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1
At local axis: 2
Integration Section: (a)
Section Type: rctcs

Constant Properties

Knowledge Factor, = 0.85

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 = 20.00

Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44

Concrete Elasticity, Ec = 21019.039

Steel Elasticity, Es = 200000.00

Max Height, Hmax = 300.00

Min Height, Hmin = 150.00

Max Width, Wmax = 300.00

Min Width, Wmin = 150.00

Eccentricity, Ecc = 75.00

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, $M = -1.8497E+007$
Shear Force, $V2 = -38091.238$
Shear Force, $V3 = 16.64536$
Axial Force, $F = -997748.352$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 2375.044$
-Compression: $A_{sc} = 2777.168$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten} = 2261.947$
-Compression: $A_{sc,com} = 829.3805$
-Middle: $A_{st,mid} = 2060.885$
Mean Diameter of Tension Reinforcement, $D_bL = 17.77778$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.03962672$
 $u = y + p = 0.04661967$

- Calculation of y -

 $y = (M_y * L_s / 3) / E_{eff} = 0.04661967$ ((4.29), Biskinis Phd)
 $M_y = 1.5916E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 6000.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 6.8279E+012$
factor = 0.70
 $A_g = 67500.00$
 $f_c' = 20.00$
 $N = 997748.352$
 $E_c * I_g = 9.7541E+012$

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, $b = 300.00$
web width, $b_w = 150.00$
flange thickness, $t = 150.00$

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 2.1407009E-005$
with $f_y = 444.44$
 $d = 257.00$
 $y = 0.59608123$
 $A = 0.25322465$
 $B = 0.16961329$
with $p_t = 0.00404182$
 $p_c = 0.0107572$
 $p_v = 0.02673002$
 $N = 997748.352$
 $b = 300.00$
 $" = 0.16731518$
 $y_{comp} = 9.3801060E-006$
with $f_c = 20.00$
 $E_c = 21019.039$
 $y = 0.71047496$

$$A = 0.11943233$$

$$B = 0.11137837$$

with $E_s = 200000.00$

CONFIRMATION: $y = 0.71047496 > t/d$

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 $V_y E / V_{CoI} E = 1.14818$

$$d = 257.00$$

$$s = 150.00$$

$$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00404182$$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 660.00$, 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.

$$N_{UD} = 997748.352$$

$$A_g = 67500.00$$

$$f_{cE} = 20.00$$

$$f_{ytE} = f_{ylE} = 444.44$$

$$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.06682506$$

$$b = 300.00$$

$$d = 257.00$$

$$f_{cE} = 20.00$$

End Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 11

column C1, Floor 1

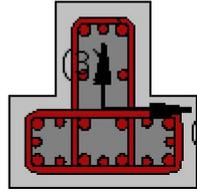
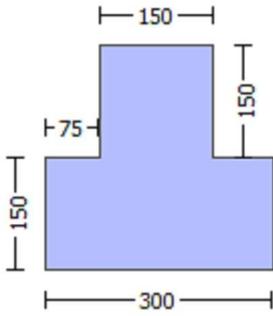
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

Max Height, $H_{max} = 300.00$

Min Height, $H_{min} = 150.00$

Max Width, $W_{max} = 300.00$

Min Width, $W_{min} = 150.00$

Eccentricity, $Ecc = 75.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou,min} = l_b/d >= 1$)

No FRP Wrapping

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -1.8497E+007$

Shear Force, $V_a = 16.64536$

EDGE -B-

Bending Moment, $M_b = -22002.95$

Shear Force, $V_b = -16.64536$

BOTH EDGES

Axial Force, $F = -997748.352$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 2375.044$

-Compression: $A_{sc} = 2777.168$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 2261.947$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 2060.885$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.77778$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 109306.383$
 V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoI} = 128595.745$
 $V_{CoI} = 128595.745$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.13206658$

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + \phi V_f$ '
where V_f is the contribution of FRPs ((11.3), ACI 440).

= 1 (normal-weight concrete)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 1.8497E+007$
 $V_u = 16.64536$
 $d = 0.8 \cdot h = 240.00$
 $N_u = 997748.352$
 $A_g = 45000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 66138.793$
where:
 $V_{s1} = 66138.793$ is calculated for section web, with:
 $d = 240.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 190.00$
 V_{s1} is multiplied by $Col1 = 0.83333333$
 $s/d = 0.79166667$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 120.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 190.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.58333$
 V_f ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: $V_s + V_f \leq 95659.751$
 $bw = 150.00$

$displacement_ductility_demand$ is calculated as ϕ / y

- Calculation of ϕ / y for END A -
for rotation axis 2 and integ. section (a)

From analysis, chord rotation $\theta = 0.0061569$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.04661967$ ((4.29), Biskinis Phd))
 $M_y = 1.5916E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 6000.00
From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 6.8279E+012$
 $factor = 0.70$
 $A_g = 67500.00$
 $f_c' = 20.00$
 $N = 997748.352$
 $E_c \cdot I_g = 9.7541E+012$

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, $b = 300.00$

web width, $b_w = 150.00$

flange thickness, $t = 150.00$

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$

$y_{\text{ten}} = 2.1407009\text{E-}005$

with $f_y = 444.44$

$d = 257.00$

$y = 0.59608123$

$A = 0.25322465$

$B = 0.16961329$

with $p_t = 0.02933783$

$p_c = 0.0107572$

$p_v = 0.02673002$

$N = 997748.352$

$b = 300.00$

" = 0.16731518

$y_{\text{comp}} = 9.3801060\text{E-}006$

with $f_c = 20.00$

$E_c = 21019.039$

$y = 0.71047496$

$A = 0.11943233$

$B = 0.11137837$

with $E_s = 200000.00$

CONFIRMATION: $y = 0.71047496 > t/d$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

End Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 12

column C1, Floor 1

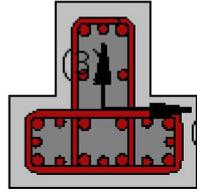
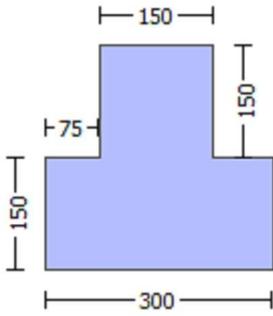
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_u)

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At Shear local axis: 3
 (Bending local axis: 2)
 Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 0.85$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$

 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

 Max Height, $H_{max} = 300.00$
 Min Height, $H_{min} = 150.00$
 Max Width, $W_{max} = 300.00$
 Min Width, $W_{min} = 150.00$
 Eccentricity, $Ecc = 75.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.00
 Element Length, $L = 3000.00$

Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{ou}, \min >= 1$)
 No FRP Wrapping

Stepwise Properties

At local axis: 3
 EDGE -A-
 Shear Force, $V_a = -1.1623543E-006$
 EDGE -B-
 Shear Force, $V_b = 1.1623543E-006$
 BOTH EDGES
 Axial Force, $F = -1.0007E+006$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{st} = 0.00$
 -Compression: $A_{sc} = 5152.212$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{st,ten} = 2261.947$
 -Compression: $A_{st,com} = 829.3805$
 -Middle: $A_{st,mid} = 2060.885$

Calculation of Shear Capacity ratio , $V_e/V_r = 1.14818$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 160672.713$

with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 2.4101E+008$

$\mu_{1+} = 1.4763E+008$, 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

$\mu_{1-} = 2.4101E+008$, 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 2.4101E+008$

$\mu_{2+} = 1.4763E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$\mu_{2-} = 2.4101E+008$, 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:

$\mu = 1.6767311E-005$

$M_u = 1.4763E+008$

with full section properties:

$b = 150.00$

$d = 257.00$

$d' = 43.00$

$v = 1.29793$

$N = 1.0007E+006$

$f_c = 20.00$

α_0 (5A.5, TBDY) = 0.002

Final value of α_0 : $\alpha_0^* = \text{shear_factor} * \text{Max}(\alpha_0, \alpha_c) = 0.0035$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\alpha_0 = 0.0035$

α_w (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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$\rho_{sh,min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.00404182$

Expression ((5.4d), TBDY) for $\rho_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\rho_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along Y) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

$\rho_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along X) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

$s = 190.00$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

From (5A.5), TBDY, TBDY: $cc = 0.002$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, 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

$$l_0/l_{ou,min} = l_b/l_{b,min} = 1.00$$

$$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs_2 = fs = 555.55$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

$$fy_v = 555.55$$

$$suv = 0.032$$

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

$$l_0/l_{ou,min} = l_b/l_d = 1.00$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fsv = fs = 555.55$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (fs_1/fc) = 1.62986$$

$$2 = A_{sl,com}/(b*d) * (fs_2/fc) = 0.59761649$$

$$v = A_{sl,mid}/(b*d) * (fsv/fc) = 1.48499$$

and confined core properties:

$$b = 90.00$$

$$d = 227.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 20.00$$

$$cc (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = A_{sl,ten}/(b*d) * (fs_1/fc) = 3.07544$$

$$2 = A_{sl,com}/(b*d) * (fs_2/fc) = 1.12766$$

$$v = A_{sl,mid}/(b*d) * (fsv/fc) = 2.80207$$

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)

---->

$v < v_{s,y1}$ - LHS eq.(4.7) is not satisfied

---->

$v < v_{c,y1}$ - RHS eq.(4.6) is not satisfied

---->

c_u (4.11) = 0.81221594

M_{Rc} (4.18) = 1.4763E+008

---->

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o
- N, ν_1, ν_2, ν normalised to $b_o d_o$, instead of $b d$
- f_{cc}, c_{cc} parameters of confined concrete, f_{cc}, c_{cc} , used in lieu of f_c, 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) = 0.91366546

M_{Ro} (4.18) = 8.4535E+007

$M_{Ro} < 0.8 * M_{Rc}$

---->

$u = c_u$ (unconfined full section) = 1.6767311E-005

$\mu_u = M_{Ro}$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_{u1} -

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$u = 1.8792920E-005$

$\mu_u = 2.4101E+008$

with full section properties:

$b = 300.00$

$d = 257.00$

$d' = 43.00$

$\nu = 0.64896668$

$N = 1.0007E+006$

$f_c = 20.00$

c_o (5A.5, TBDY) = 0.002

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0035$

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along Y) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along X) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

$s = 190.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.002$

c = confinement factor = 1.00

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$su_1 = 0.4 * e_{su1_nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $e_{su1_nominal} = 0.08$,

For calculation of $e_{su1_nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $f_{sy1} = f_s/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $f_{s1} = f_s = 555.55$

with $E_{s1} = E_s = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 * e_{su2_nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $e_{su2_nominal} = 0.08$,

For calculation of $e_{su2_nominal}$ and y_2 , sh_2 , ft_2 , fy_2 , it is considered characteristic value $f_{sy2} = f_s/1.2$, from table 5.1, TBDY.

y_2 , sh_2 , ft_2 , fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $f_{s2} = f_s = 555.55$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.00231479$

```

shv = 0.008
ftv = 666.66
fyv = 555.55
suv = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^2/3), from 10.3.5, ASCE 41-17.
with fsv = fs = 555.55
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.29880825
2 = Asl,com/(b*d)*(fs2/fc) = 0.81493158
v = Asl,mid/(b*d)*(fsv/fc) = 0.74249322
and confined core properties:
b = 240.00
d = 227.00
d' = 13.00
fcc (5A.2, TBDY) = 20.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.4228729
2 = Asl,com/(b*d)*(fs2/fc) = 1.15329
v = Asl,mid/(b*d)*(fsv/fc) = 1.05078
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) = 0.45266836
MRC (4.17) = 2.7366E+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) = 0.46882405

```

$$M_{Ro} (4.18) = 2.4101E+008$$

--->

$$u = c_u (4.2) = 1.8792920E-005$$

$$\mu = M_{Ro}$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$u = 1.6767311E-005$$

$$\mu = 1.4763E+008$$

with full section properties:

$$b = 150.00$$

$$d = 257.00$$

$$d' = 43.00$$

$$v = 1.29793$$

$$N = 1.0007E+006$$

$$f_c = 20.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0035$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0035$$

$$w_e (5.4c) = 0.00$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} (\text{Length of stirrups along } Y) = 660.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 67500.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} (\text{Length of stirrups along } X) = 660.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

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) = 1.62986

2 = Asl,com/(b*d)*(fs2/fc) = 0.59761649

v = Asl,mid/(b*d)*(fsv/fc) = 1.48499

and confined core properties:

b = 90.00

d = 227.00

d' = 13.00

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

1 = Asl,ten/(b*d)*(fs1/fc) = 3.07544

2 = Asl,com/(b*d)*(fs2/fc) = 1.12766

v = Asl,mid/(b*d)*(fsv/fc) = 2.80207

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)

--->
 $v < s_y y_1$ - LHS eq.(4.7) is not satisfied
 --->
 $v < v_c y_1$ - RHS eq.(4.6) is not satisfied
 --->
 ϵ_{cu} (4.11) = 0.81221594
 M_{Rc} (4.18) = 1.4763E+008
 --->
 New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
 In expressions below, the following modifications have been made
 - b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o
 - $N, \epsilon_1, \epsilon_2, v$ normalised to $b_o d_o$, instead of $b d$
 - f_{cc}, ϵ_{cc} parameters of confined concrete, f_{cc}, ϵ_{cc} , used in lieu of f_c, ϵ_{cu}

--->
Subcase: Rupture of tension steel

--->
 $v^* < v^* s_y y_2$ - LHS eq.(4.5) is not satisfied

--->
 $v^* < v^* s_c$ - LHS eq.(4.5) is not satisfied

--->
Subcase rejected

--->
New Subcase: Failure of compression zone

--->
 $v^* < v^* c_y y_2$ - LHS eq.(4.6) is not satisfied

--->
 $v^* < v^* c_y y_1$ - RHS eq.(4.6) is not satisfied

--->
 ϵ_{cu}^* (4.11) = 0.91366546
 M_{Ro} (4.18) = 8.4535E+007

$M_{Ro} < 0.8 M_{Rc}$

--->
 $\epsilon_u = \epsilon_{cu}$ (unconfined full section) = 1.6767311E-005

$M_u = M_{Rc}$

Calculation of ratio I_b/I_d

Adequate Lap Length: $I_b/I_d \geq 1$

Calculation of M_{u2}

Calculation of ultimate curvature ϵ_u according to 4.1, Biskinis/Fardis 2013:

$\epsilon_u = 1.8792920E-005$

$M_u = 2.4101E+008$

with full section properties:

$b = 300.00$

$d = 257.00$

$d' = 43.00$

$v = 0.64896668$

$N = 1.0007E+006$

$f_c = 20.00$

ϵ_{co} (5A.5, TBDY) = 0.002

Final value of ϵ_{cu} : $\epsilon_{cu}^* = \text{shear_factor} * \text{Max}(\epsilon_{cu}, \epsilon_{cc}) = 0.0035$

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

$\epsilon_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along Y) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

 $p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along X) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

 $s = 190.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.002$

$c = \text{confinement factor} = 1.00$

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$su_1 = 0.4 * esu1_{nominal}$ ((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 $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$\rho_{sv} = 0.4 \cdot \rho_{sv,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $\rho_{sv,nominal} = 0.08$,
 considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $\rho_{sv,nominal}$ and ρ_{sv} , $\rho_{shv}, \rho_{ftv}, \rho_{fyv}$, it is considered
 characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.
 $\rho_{y1}, \rho_{sh1}, \rho_{ft1}, \rho_{fy1}$, are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $f_{sv} = f_s = 555.55$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.29880825$
 $2 = A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.81493158$
 $v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.74249322$

and confined core properties:

$b = 240.00$
 $d = 227.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.4228729$
 $2 = A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 1.15329$
 $v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 1.05078$

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)

--->

$v < v_{s,y1}$ - LHS eq.(4.7) is not satisfied

--->

$v < v_{c,y1}$ - RHS eq.(4.6) is satisfied

--->

$\rho_{cu} (4.10) = 0.45266836$
 $M_{Rc} (4.17) = 2.7366E+008$

--->

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, ρ_{cc}

--->

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

--->

$\rho_{cu} (4.11) = 0.46882405$
 $M_{Ro} (4.18) = 2.4101E+008$

--->

$u = \rho_{cu} (4.2) = 1.8792920E-005$
 $M_u = M_{Ro}$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 139936.984$

Calculation of Shear Strength at edge 1, $V_{r1} = 139936.984$

$V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = knl * V_{Co10}$

$V_{Co10} = 139936.984$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf' where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$M_u = 934188.794$

$V_u = 1.1623543E-006$

$d = 0.8 * h = 240.00$

$N_u = 1.0007E+006$

$A_g = 45000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

$V_{s1} = 73486.813$ is calculated for section web, with:

$d = 240.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 190.00$

V_{s1} is multiplied by $Col1 = 0.83333333$

$s/d = 0.79166667$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 120.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 190.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.58333$

$V_f ((11-3)-(11.4), ACI 440) = 0.00$

From (11-11), ACI 440: $V_s + V_f \leq 106950.853$

$b_w = 150.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 139936.984$

$V_{r2} = V_{Co2} ((10.3), ASCE 41-17) = knl * V_{Co10}$

$V_{Co10} = 139936.984$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf' where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$M_u = 760.756$

$V_u = 1.1623543E-006$

$d = 0.8 * h = 240.00$

$N_u = 1.0007E+006$

$A_g = 45000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

$V_{s1} = 73486.813$ is calculated for section web, with:

$d = 240.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 190.00$

Vs1 is multiplied by Col1 = 0.83333333
s/d = 0.79166667
Vs2 = 0.00 is calculated for section flange, with:
d = 120.00
Av = 157079.633
fy = 444.44
s = 190.00
Vs2 is multiplied by Col2 = 0.00
s/d = 1.58333
Vf ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: Vs + Vf <= 106950.853
bw = 150.00

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rctcs

Constant Properties

Knowledge Factor, = 0.85
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00
Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44
Concrete Elasticity, Ec = 21019.039
Steel Elasticity, Es = 200000.00

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, fs = 1.25*fsm = 555.55

Max Height, Hmax = 300.00
Min Height, Hmin = 150.00
Max Width, Wmax = 300.00
Min Width, Wmin = 150.00
Eccentricity, Ecc = 75.00
Cover Thickness, c = 25.00
Mean Confinement Factor overall section = 1.00
Element Length, L = 3000.00
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length (lo/lou,min >= 1)
No FRP Wrapping

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, Va = -5.7446150E-009
EDGE -B-
Shear Force, Vb = 5.7446150E-009
BOTH EDGES
Axial Force, F = -1.0007E+006
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00

-Compression: $As_{lc} = 5152.212$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{l,ten} = 1231.504$
 -Compression: $As_{l,com} = 1231.504$
 -Middle: $As_{l,mid} = 2689.203$

 Calculation of Shear Capacity ratio , $V_e/V_r = 0.62533189$
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 129060.47$
 with

$M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 1.9359E+008$
 $Mu_{1+} = 1.9359E+008$, 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
 $Mu_{1-} = 1.9359E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 1.9359E+008$
 $Mu_{2+} = 1.9359E+008$, 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
 $Mu_{2-} = 1.9359E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

 Calculation of Mu_{1+}

 Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 1.9679130E-005$
 $M_u = 1.9359E+008$

 with full section properties:

$b = 150.00$
 $d = 257.00$
 $d' = 43.00$
 $\nu = 1.29793$
 $N = 1.0007E+006$
 $f_c = 20.00$
 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.
 $A_{conf,max} = 35100.00$ is the 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.
 $A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $\phi_{psh,min} = \text{Min}(\phi_{psh,x} , \phi_{psh,y}) = 0.00404182$
 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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$
 L_{stir} (Length of stirrups along Y) = 660.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 67500.00

$\phi_{psh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

Lstir (Length of stirrups along X) = 660.00
Astir (stirrups area) = 78.53982
Asec (section area) = 67500.00

s = 190.00

fywe = 555.55

fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/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) = 0.88736994

2 = Asl,com/(b*d)*(fs2/fc) = 0.88736994

v = Asl,mid/(b*d)*(fsv/fc) = 1.93773

and confined core properties:

b = 90.00

d = 227.00

d' = 13.00

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00
1 = $Asl,ten/(b*d)*(fs1/fc) = 1.67441$
2 = $Asl,com/(b*d)*(fs2/fc) = 1.67441$
v = $Asl,mid/(b*d)*(fsv/fc) = 3.65636$

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) = 0.69203654
MRc (4.18) = 1.9359E+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) = 0.73305448
MRo (4.18) = 1.3270E+008

MRo < 0.8*MRc

---->
u = cu (unconfined full section) = 1.9679130E-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 = 1.9679130E-005
Mu = 1.9359E+008

with full section properties:

b = 150.00
d = 257.00
d' = 43.00

$$v = 1.29793$$

$$N = 1.0007E+006$$

$$f_c = 20.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0035$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0035$$

$$w_e (5.4c) = 0.00$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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., 10.11061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} (\text{Length of stirrups along Y}) = 660.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 67500.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} (\text{Length of stirrups along X}) = 660.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{1,nominal} = 0.08,$$

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs_1 = fs = 555.55$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$$

$$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{2,nominal} = 0.08,$$

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered

characteristic value $f_{s2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, 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 $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $f_{sv} = f_{sv}/1.2$, 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 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.88736994$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.88736994$

$v = Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 1.93773$

and confined core properties:

$b = 90.00$

$d = 227.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 20.00$

$cc (5A.5, TBDY) = 0.002$

$c = \text{confinement factor} = 1.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 1.67441$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 1.67441$

$v = Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 3.65636$

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

--->

$cu (4.11) = 0.69203654$

$M_{Rc} (4.18) = 1.9359E+008$

--->

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

--->

*cu (4.11) = 0.73305448

M_{Ro} (4.18) = 1.3270E+008

M_{Ro} < 0.8*M_{Rc}

--->

u = cu (unconfined full section) = 1.9679130E-005

Mu = M_{Rc}

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 = 1.9679130E-005

Mu = 1.9359E+008

with full section properties:

b = 150.00

d = 257.00

d' = 43.00

v = 1.29793

N = 1.0007E+006

f_c = 20.00

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(((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} = 35100.00 is the 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} = 16650.00 is the unconfined core area which is equal to bi²/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00404182

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) = L_{stir}*A_{stir}/(A_{sec}*s) = 0.00404182

L_{stir} (Length of stirrups along Y) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

psh,y ((5.4d), TBDY) = L_{stir}*A_{stir}/(A_{sec}*s) = 0.00404182

L_{stir} (Length of stirrups along X) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

s = 190.00

f_{ywe} = 555.55

f_{ce} = 20.00

From ((5.A.5), TBDY), TBDY: $cc = 0.002$
 $c = \text{confinement factor} = 1.00$

$y1 = 0.00231479$

$sh1 = 0.008$

$ft1 = 666.66$

$fy1 = 555.55$

$su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou,min = lb/d = 1.00$

$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, 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 $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, 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 $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fsv = fs = 555.55$

with $Esv = Es = 200000.00$

$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.88736994$

$2 = Asl,com / (b * d) * (fs2 / fc) = 0.88736994$

$v = Asl,mid / (b * d) * (fsv / fc) = 1.93773$

and confined core properties:

$b = 90.00$

$d = 227.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 20.00$

$cc (5A.5, TBDY) = 0.002$

$c = \text{confinement factor} = 1.00$

$1 = Asl,ten / (b * d) * (fs1 / fc) = 1.67441$

$2 = Asl,com / (b * d) * (fs2 / fc) = 1.67441$

$v = Asl,mid / (b * d) * (fsv / fc) = 3.65636$

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) = 0.69203654

M_{Rc} (4.18) = 1.9359E+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
- N₁, N₂, 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_{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) = 0.73305448

M_{Ro} (4.18) = 1.3270E+008

M_{Ro} < 0.8*M_{Rc}

--->

u = cu (unconfined full section) = 1.9679130E-005

Mu = M_{Rc}

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 = 1.9679130E-005

Mu = 1.9359E+008

with full section properties:

b = 150.00

d = 257.00

d' = 43.00

v = 1.29793

N = 1.0007E+006

f_c = 20.00

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} (\text{Length of stirrups along } Y) = 660.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 67500.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} (\text{Length of stirrups along } X) = 660.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

From ((5.A5), TBDY), TBDY: $c_c = 0.002$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, 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

$$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$$

$$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$$

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/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) = 0.88736994
2 = Asl,com/(b*d)*(fs2/fc) = 0.88736994
v = Asl,mid/(b*d)*(fsv/fc) = 1.93773
and confined core properties:
b = 90.00
d = 227.00
d' = 13.00
fcc (5A.2, TBDY) = 20.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 1.67441
2 = Asl,com/(b*d)*(fs2/fc) = 1.67441
v = Asl,mid/(b*d)*(fsv/fc) = 3.65636
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) = 0.69203654
MRc (4.18) = 1.9359E+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) = 0.73305448
MRo (4.18) = 1.3270E+008
MRo < 0.8*MRc

```

--->

$u = cu$ (unconfined full section) = $1.9679130E-005$
 $\mu = MRc$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 206387.155$

Calculation of Shear Strength at edge 1, $V_{r1} = 206387.155$
 $V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l * V_{Col0}$
 $V_{Col0} = 206387.155$
 $k_n l = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 $f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu = 1446.319$
 $V_u = 5.7446150E-009$
 $d = 0.8 * h = 240.00$
 $N_u = 1.0007E+006$
 $A_g = 45000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$
where:
 $V_{s1} = 0.00$ is calculated for section web, with:
 $d = 120.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 190.00$
 V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 1.58333$
 $V_{s2} = 73486.813$ is calculated for section flange, with:
 $d = 240.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 190.00$
 V_{s2} is multiplied by $Col2 = 0.83333333$
 $s/d = 0.79166667$
 V_f ((11-3)-(11.4), ACI 440) = 0.00
From (11-11), ACI 440: $V_s + V_f \leq 106950.853$
 $b_w = 150.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 206387.155$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l * V_{Col0}$
 $V_{Col0} = 206387.155$
 $k_n l = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 $f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu = 0.02042443$
 $V_u = 5.7446150E-009$
 $d = 0.8 * h = 240.00$
 $N_u = 1.0007E+006$
 $A_g = 45000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 120.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 190.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 1.58333$

$V_{s2} = 73486.813$ is calculated for section flange, with:

$d = 240.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 190.00$

V_{s2} is multiplied by $Col2 = 0.833333333$

$s/d = 0.791666667$

V_f ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: $V_s + V_f \leq 106950.853$

$bw = 150.00$

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1
At local axis: 3
Integration Section: (a)
Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 300.00$

Min Height, $H_{min} = 150.00$

Max Width, $W_{max} = 300.00$

Min Width, $W_{min} = 150.00$

Eccentricity, $Ecc = 75.00$

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, $M = -2.9481E+008$

Shear Force, $V_2 = -38091.238$

Shear Force, $V_3 = 16.64536$

Axial Force, $F = -997748.352$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 2375.044$

-Compression: $As_c = 2777.168$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{s,ten} = 1231.504$

-Compression: $A_{s,com} = 1231.504$

-Middle: $A_{s,mid} = 2689.203$

Mean Diameter of Tension Reinforcement, $D_bL = 17.60$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u,R = * u = 0.03358623$

$u = y + p = 0.03951321$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.03951321$ ((4.29), Biskinis Phd))

$M_y = 1.1037E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 6000.00

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 5.5865E+012$

factor = 0.70

$A_g = 67500.00$

$f_c' = 20.00$

$N = 997748.352$

$E_c * I_g = 7.9807E+012$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 2.2090882E-005$

with $f_y = 444.44$

$d = 257.00$

$y = 0.60858546$

$A = 0.19188504$

$B = 0.13624083$

with $p_t = 0.00404182$

$p_c = 0.03194564$

$p_v = 0.06975884$

$N = 997748.352$

$b = 150.00$

" = 0.16731518

$y_{comp} = 8.4879027E-006$

with $f_c = 20.00$

$E_c = 21019.039$

$y = 0.78515631$

$A = 0.05809272$

$B = 0.0780059$

with $E_s = 200000.00$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

- Calculation of p -

From table 10-8: $p = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$

shear control ratio $V_y E / V_{col} O E = 0.62533189$

$d = 257.00$

$s = 150.00$

$t = A_v / (b w * s) + 2 * t_f / b w * (f_f e / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b w * (f_f e / f_s) = 0.00404182$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 660.00$, 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.

$N_{UD} = 997748.352$

$A_g = 67500.00$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 444.44$

$\rho_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.13365012$

$b = 150.00$

$d = 257.00$

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 13

column C1, Floor 1

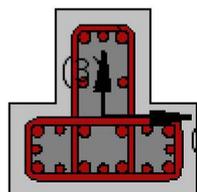
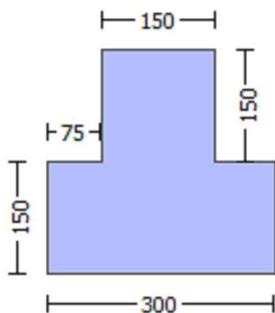
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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, $f_c = f_{c_lower_bound} = 16.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of μ 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, $f_c = f_{cm} = 20.00$
 Existing material: Steel Strength, $f_s = f_{sm} = 444.44$
 #####
 Max Height, $H_{max} = 300.00$
 Min Height, $H_{min} = 150.00$
 Max Width, $W_{max} = 300.00$
 Min Width, $W_{min} = 150.00$
 Eccentricity, $Ecc = 75.00$
 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, $M_a = -2.9481E+008$
 Shear Force, $V_a = -38091.238$
 EDGE -B-
 Bending Moment, $M_b = -7.6430E+006$
 Shear Force, $V_b = 38091.238$
 BOTH EDGES
 Axial Force, $F = -997748.352$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{st} = 0.00$
 -Compression: $A_{sc} = 5152.212$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{st,ten} = 1231.504$
 -Compression: $A_{st,com} = 1231.504$
 -Middle: $A_{st,mid} = 2689.203$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.60$

 Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 113676.355$
 V_n ((10.3), ASCE 41-17) = $k_n l V_{CoI} = 133736.888$
 $V_{CoI} = 191052.697$
 $k_n l = 0.70$
 displacement_ductility_demand = 8.96571

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)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 7.6430E+006$
 $V_u = 38091.238$
 $d = 0.8 \cdot h = 240.00$

$Nu = 997748.352$
 $Ag = 45000.00$
 From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 66138.793$
 where:
 $Vs1 = 0.00$ is calculated for section web, with:
 $d = 120.00$
 $Av = 157079.633$
 $fy = 400.00$
 $s = 190.00$
 $Vs1$ is multiplied by $Col1 = 0.00$
 $s/d = 1.58333$
 $Vs2 = 66138.793$ is calculated for section flange, with:
 $d = 240.00$
 $Av = 157079.633$
 $fy = 400.00$
 $s = 190.00$
 $Vs2$ is multiplied by $Col2 = 0.833333333$
 $s/d = 0.79166667$
 $Vf ((11-3)-(11.4), ACI 440) = 0.00$
 From (11-11), ACI 440: $Vs + Vf \leq 95659.751$
 $bw = 150.00$

displacement ductility demand is calculated as δ / y

- Calculation of δ / y for END B -
for rotation axis 3 and integ. section (b)

From analysis, chord rotation $\theta = 0.01771319$
 $y = (My * Ls / 3) / Eleff = 0.00197566$ ((4.29), Biskinis Phd)
 $My = 1.1037E+008$
 $Ls = M/V$ (with $Ls > 0.1 * L$ and $Ls < 2 * L$) = 300.00
 From table 10.5, ASCE 41_17: $Eleff = factor * Ec * I_g = 5.5865E+012$
 $factor = 0.70$
 $Ag = 67500.00$
 $fc' = 20.00$
 $N = 997748.352$
 $Ec * I_g = 7.9807E+012$

Calculation of Yielding Moment My

Calculation of δ / y and My according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 2.2090882E-005$
 with $fy = 444.44$
 $d = 257.00$
 $y = 0.60858546$
 $A = 0.19188504$
 $B = 0.13624083$
 with $pt = 0.03194564$
 $pc = 0.03194564$
 $p_v = 0.06975884$
 $N = 997748.352$
 $b = 150.00$
 $\rho = 0.16731518$
 $y_{comp} = 8.4879027E-006$
 with $fc = 20.00$
 $Ec = 21019.039$
 $y = 0.78515631$
 $A = 0.05809272$
 $B = 0.0780059$
 with $Es = 200000.00$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

End Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 14

column C1, Floor 1

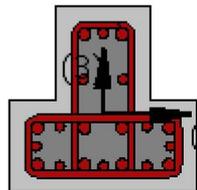
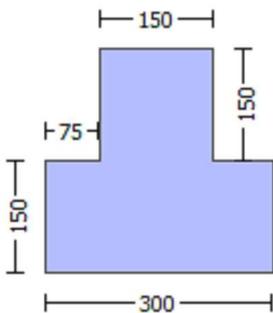
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\phi = 0.85$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height, Hmax = 300.00
Min Height, Hmin = 150.00
Max Width, Wmax = 300.00
Min Width, Wmin = 150.00
Eccentricity, Ecc = 75.00
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 ($l_o/l_{o,min} \geq 1$)
No FRP Wrapping

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, Va = -1.1623543E-006
EDGE -B-
Shear Force, Vb = 1.1623543E-006
BOTH EDGES
Axial Force, F = -1.0007E+006
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 5152.212
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 2261.947
-Compression: Asl,com = 829.3805
-Middle: Asl,mid = 2060.885

Calculation of Shear Capacity ratio , $V_e/V_r = 1.14818$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 160672.713$
with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 2.4101E+008$
 $\mu_{u1+} = 1.4763E+008$, 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
 $\mu_{u1-} = 2.4101E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 2.4101E+008$
 $\mu_{u2+} = 1.4763E+008$, 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
 $\mu_{u2-} = 2.4101E+008$, 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:
 $\phi_u = 1.6767311E-005$
 $\mu_u = 1.4763E+008$

with full section properties:

b = 150.00
d = 257.00
d' = 43.00
v = 1.29793
N = 1.0007E+006

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0035$$

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 660.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 67500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along X)} = 660.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{1,nominal} = 0.08,$$

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1 / 1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$, from 10.3.5, 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

$$l_o / l_{ou,min} = l_b / l_{b,min} = 1.00$$

$$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{2,nominal} = 0.08,$$

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2 / 1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$, from 10.3.5, 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 Bisquis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $f_{syv} = f_{sv}/1.2$, 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 $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $f_{sv} = f_s = 555.55$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 1.62986$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.59761649$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 1.48499$
 and confined core properties:
 $b = 90.00$
 $d = 227.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 3.07544$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 1.12766$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 2.80207$
 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
 --->
 $cu (4.11) = 0.81221594$
 $M_{Rc} (4.18) = 1.4763E+008$
 --->
 New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
 In expressions below, the following modifications have been made
 - b, d, d' replaced by geometric parameters of the core: $bo, do, d'o$
 - $N, 1, 2, v$ normalised to $bo*do$, instead of $b*d$
 - - parameters of confined concrete, f_{cc}, cc , used in lieu of f_c, 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) = 0.91366546

M_{Ro} (4.18) = 8.4535E+007

M_{Ro} < 0.8*M_{Rc}

--->

u = cu (unconfined full section) = 1.6767311E-005

Mu = M_{Rc}

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 = 1.8792920E-005

Mu = 2.4101E+008

with full section properties:

b = 300.00

d = 257.00

d' = 43.00

v = 0.64896668

N = 1.0007E+006

f_c = 20.00

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(((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} = 35100.00 is the 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} = 16650.00 is the unconfined core area which is equal to bi²/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00404182

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) = L_{stir}*A_{stir}/(A_{sec}*s) = 0.00404182

L_{stir} (Length of stirrups along Y) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

psh,y ((5.4d), TBDY) = L_{stir}*A_{stir}/(A_{sec}*s) = 0.00404182

L_{stir} (Length of stirrups along X) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

s = 190.00

f_{ywe} = 555.55

f_{ce} = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/d = 1.00$$

$$su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, 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 $\text{Min}(1, 1.25*(lb/d)^{2/3})$, 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

$$lo/lou,min = lb/d = 1.00$$

$$suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fsv = fs = 555.55$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.29880825$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.81493158$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.74249322$$

and confined core properties:

$$b = 240.00$$

$$d = 227.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 20.00$$

$$cc (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.4228729$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 1.15329$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 1.05078$$

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) = 0.45266836

M_{Rc} (4.17) = 2.7366E+008

---->

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o

- $N, 1, 2, v$ normalised to $b_o * d_o$, instead of $b * d$

- - parameters of confined concrete, f_{cc}, c_c , used in lieu of f_c, c_u

---->

Subcase: Rupture of tension steel

---->

$v^* < v^* s, y2$ - LHS eq.(4.5) is not satisfied

---->

$v^* < v^* s, c$ - LHS eq.(4.5) is not satisfied

---->

Subcase rejected

---->

New Subcase: Failure of compression zone

---->

$v^* < v^* c, y2$ - LHS eq.(4.6) is not satisfied

---->

$v^* < v^* c, y1$ - RHS eq.(4.6) is not satisfied

---->

* c_u (4.11) = 0.46882405

M_{Ro} (4.18) = 2.4101E+008

---->

$u = c_u$ (4.2) = 1.8792920E-005

$\mu = M_{Ro}$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_{2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 1.6767311E-005$

$\mu = 1.4763E+008$

with full section properties:

$b = 150.00$

$d = 257.00$

$d' = 43.00$

$v = 1.29793$

$N = 1.0007E+006$

$f_c = 20.00$

c_o (5A.5, TBDY) = 0.002

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0035$

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

$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$

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)

 $p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along Y) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

 $p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along X) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

 $s = 190.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.002$

$c = \text{confinement factor} = 1.00$

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{u,min} = lb/ld = 1.00$

$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{u,min} = lb/lb_{,min} = 1.00$

$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, 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/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) = 1.62986
2 = Asl,com/(b*d)*(fs2/fc) = 0.59761649
v = Asl,mid/(b*d)*(fsv/fc) = 1.48499
and confined core properties:
b = 90.00
d = 227.00
d' = 13.00
fcc (5A.2, TBDY) = 20.00
cc (5A.5, TBDY) = 0.002
  c = confinement factor = 1.00
  1 = Asl,ten/(b*d)*(fs1/fc) = 3.07544
  2 = Asl,com/(b*d)*(fs2/fc) = 1.12766
  v = Asl,mid/(b*d)*(fsv/fc) = 2.80207
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) = 0.81221594
  MRc (4.18) = 1.4763E+008
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o
- N, 1, 2, v normalised to bo*do, instead of b*d
- - parameters of confined concrete, fcc, cc, used in lieu of fc, ecu
---->
Subcase: Rupture of tension steel
---->
v* < v*sy2 - LHS eq.(4.5) is not satisfied
---->
v* < v*sc - LHS eq.(4.5) is not satisfied
---->
Subcase rejected
---->
New Subcase: Failure of compression zone
---->
v* < v*c,y2 - LHS eq.(4.6) is not satisfied
---->
v* < v*c,y1 - RHS eq.(4.6) is not satisfied
---->
  *cu (4.11) = 0.91366546
  MRo (4.18) = 8.4535E+007
  MRo < 0.8*MRc
---->
  u = cu (unconfined full section) = 1.6767311E-005
  Mu = MRc

```

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_2

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.8792920E-005$$

$$\mu_2 = 2.4101E+008$$

with full section properties:

$$b = 300.00$$

$$d = 257.00$$

$$d' = 43.00$$

$$v = 0.64896668$$

$$N = 1.0007E+006$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_2: \mu_2^* = \text{shear_factor} * \text{Max}(\mu_2, c_c) = 0.0035$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_2 = 0.0035$$

$$\mu_2 \text{ (5.4c)} = 0.00$$

$$\mu_2^* = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$\mu_2^*,min = \text{Min}(\mu_2^*,x, \mu_2^*,y) = 0.00404182$$

Expression ((5.4d), TBDY) for μ_2^*,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\mu_2^*,x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 660.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 67500.00$$

$$\mu_2^*,y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along X)} = 660.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

From ((5.A5), TBDY), TBDY: $c_c = 0.002$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 1.00$$

$$s_u1 = 0.4 * e_{s1_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s1_nominal} = 0.08$,

For calculation of $e_{s1_nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $f_{sy1} = f_s/1.2$, 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.

$$\text{with } f_{s1} = f_s = 555.55$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$s_u2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$$

$$s_u2 = 0.4 * e_{s2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s2_nominal} = 0.08$,

For calculation of $e_{s2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $f_{sy2} = f_s/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } f_{s2} = f_s = 555.55$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

$$fy_v = 555.55$$

$$s_{uv} = 0.032$$

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

$$l_o/l_{o,min} = l_b/l_d = 1.00$$

$$s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{suv_nominal} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } f_{sv} = f_s = 555.55$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.29880825$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.81493158$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.74249322$$

and confined core properties:

$$b = 240.00$$

$$d = 227.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 20.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.4228729$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 1.15329$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 1.05078$$

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) = 0.45266836
MRc (4.17) = 2.7366E+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) = 0.46882405

MRO (4.18) = 2.4101E+008

---->

u = cu (4.2) = 1.8792920E-005

Mu = MRO

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 139936.984

Calculation of Shear Strength at edge 1, Vr1 = 139936.984

Vr1 = VCol ((10.3), ASCE 41-17) = knl*VColO

VColO = 139936.984

knl = 1 (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*VF'
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

fc' = 20.00, but $fc^{0.5} <= 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 934188.794

Vu = 1.1623543E-006

d = 0.8*h = 240.00

Nu = 1.0007E+006

Ag = 45000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 73486.813

where:

Vs1 = 73486.813 is calculated for section web, with:

d = 240.00

Av = 157079.633

fy = 444.44

s = 190.00

Vs1 is multiplied by Col1 = 0.83333333

s/d = 0.79166667

Vs2 = 0.00 is calculated for section flange, with:

d = 120.00

Av = 157079.633

fy = 444.44

s = 190.00

Vs2 is multiplied by Col2 = 0.00

s/d = 1.58333

Vf ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: Vs + Vf <= 106950.853

bw = 150.00

Calculation of Shear Strength at edge 2, Vr2 = 139936.984

Vr2 = VCol ((10.3), ASCE 41-17) = knl*VCol0

VCol0 = 139936.984

knl = 1 (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

fc' = 20.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 760.756

Vu = 1.1623543E+006

d = 0.8*h = 240.00

Nu = 1.0007E+006

Ag = 45000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 73486.813

where:

Vs1 = 73486.813 is calculated for section web, with:

d = 240.00

Av = 157079.633

fy = 444.44

s = 190.00

Vs1 is multiplied by Col1 = 0.83333333

s/d = 0.79166667

Vs2 = 0.00 is calculated for section flange, with:

d = 120.00

Av = 157079.633

fy = 444.44

s = 190.00

Vs2 is multiplied by Col2 = 0.00

s/d = 1.58333

Vf ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: Vs + Vf <= 106950.853

bw = 150.00

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rctcs

Constant Properties

Knowledge Factor, = 0.85

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00

Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44

Concrete Elasticity, Ec = 21019.039

Steel Elasticity, Es = 200000.00

#####

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height, $H_{max} = 300.00$

Min Height, $H_{min} = 150.00$

Max Width, $W_{max} = 300.00$

Min Width, $W_{min} = 150.00$

Eccentricity, $Ecc = 75.00$

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, $V_a = -5.7446150E-009$

EDGE -B-

Shear Force, $V_b = 5.7446150E-009$

BOTH EDGES

Axial Force, $F = -1.0007E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1231.504$

-Compression: $As_{c,com} = 1231.504$

-Middle: $As_{mid} = 2689.203$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.62533189$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 129060.47$

with

$M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 1.9359E+008$

$Mu_{1+} = 1.9359E+008$, 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

$Mu_{1-} = 1.9359E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 1.9359E+008$

$Mu_{2+} = 1.9359E+008$, 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

$Mu_{2-} = 1.9359E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment
direction which is defined for the the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.9679130E-005$

$Mu = 1.9359E+008$

with full section properties:

b = 150.00
d = 257.00
d' = 43.00
v = 1.29793
N = 1.0007E+006

fc = 20.00
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 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.

$A_{\text{conf,max}} = 35100.00$ is the 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.

$A_{\text{noConf}} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh_{\text{min}} = \text{Min}(psh_x, psh_y) = 0.00404182$

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) = $L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00404182$

L_{stir} (Length of stirrups along Y) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

 psh_y ((5.4d), TBDY) = $L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00404182$

L_{stir} (Length of stirrups along X) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

s = 190.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = $0.4 * esu1_{\text{nominal}}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_{\text{nominal}} = 0.08$,

For calculation of $esu1_{\text{nominal}}$ and y1, sh1, ft1, fy1, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, 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

$su_2 = 0.4 * esu_2_nominal ((5.5), TBDY) = 0.032$
 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 $Es_2 = Es = 200000.00$
 $yv = 0.00231479$
 $shv = 0.008$
 $ftv = 666.66$
 $fyv = 555.55$
 $suv = 0.032$
 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.
 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 $Es_v = Es = 200000.00$
 $1 = Asl, ten / (b * d) * (fs_1 / fc) = 0.88736994$
 $2 = Asl, com / (b * d) * (fs_2 / fc) = 0.88736994$
 $v = Asl, mid / (b * d) * (fsv / fc) = 1.93773$
 and confined core properties:
 $b = 90.00$
 $d = 227.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c =$ confinement factor = 1.00
 $1 = Asl, ten / (b * d) * (fs_1 / fc) = 1.67441$
 $2 = Asl, com / (b * d) * (fs_2 / fc) = 1.67441$
 $v = Asl, mid / (b * d) * (fsv / fc) = 3.65636$
 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)
 --->
 $v < s, y_1$ - LHS eq.(4.7) is not satisfied
 --->
 $v < v_{c, y_1}$ - RHS eq.(4.6) is not satisfied
 --->
 $cu (4.11) = 0.69203654$
 $MRC (4.18) = 1.9359E+008$
 --->
 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_u
 --->
 Subcase: Rupture of tension steel
 --->
 $v^* < v^* s, y_2$ - LHS eq.(4.5) is not satisfied
 --->
 $v^* < v^* s, c$ - LHS eq.(4.5) is not satisfied
 --->
 Subcase rejected

--->

New Subcase: Failure of compression zone

--->

$v^* < v^*c,y2$ - LHS eq.(4.6) is not satisfied

--->

$v^* < v^*c,y1$ - RHS eq.(4.6) is not satisfied

--->

*cu (4.11) = 0.73305448

MRO (4.18) = 1.3270E+008

MRO < 0.8*MRc

--->

u = cu (unconfined full section) = 1.9679130E-005

Mu = MRc

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Mu1-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.9679130E-005

Mu = 1.9359E+008

with full section properties:

b = 150.00

d = 257.00

d' = 43.00

v = 1.29793

N = 1.0007E+006

fc = 20.00

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 = $\text{Max}(((Aconf,max - AnoConf)/Aconf,max) * (Aconf,min/Aconf,max), 0) = 0.00$

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 = 35100.00 is the 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 = 16650.00 is the unconfined core area which is equal to $bi^2/6$ as defined at (A.2).

psh,min = $\text{Min}(psh,x, psh,y) = 0.00404182$

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) = $Lstir * Astir / (Asec * s) = 0.00404182$

Lstir (Length of stirrups along Y) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

 psh,y ((5.4d), TBDY) = $Lstir * Astir / (Asec * s) = 0.00404182$

Lstir (Length of stirrups along X) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.002$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/ld = 1.00$$

$$su_1 = 0.4 * esu_{1, \text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

From table 5A.1, TBDY: $esu_{1, \text{nominal}} = 0.08$,

For calculation of $esu_{1, \text{nominal}}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs_1 = fs = 555.55$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00231479$$

$$sh_2 = 0.008$$

$$ft_2 = 666.66$$

$$fy_2 = 555.55$$

$$su_2 = 0.032$$

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

$$lo/lou, \min = lb/lb, \min = 1.00$$

$$su_2 = 0.4 * esu_{2, \text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

From table 5A.1, TBDY: $esu_{2, \text{nominal}} = 0.08$,

For calculation of $esu_{2, \text{nominal}}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs_2 = fs = 555.55$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

$$fy_v = 555.55$$

$$su_v = 0.032$$

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

$$lo/lou, \min = lb/ld = 1.00$$

$$su_v = 0.4 * esu_{v, \text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

From table 5A.1, TBDY: $esu_{v, \text{nominal}} = 0.08$,

considering characteristic value $fsy_v = fsv/1.2$, from table 5.1, TBDY

For calculation of $esu_{v, \text{nominal}}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsy_v = fsv/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fsv = fs = 555.55$$

$$\text{with } Es_v = Es = 200000.00$$

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.88736994$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.88736994$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 1.93773$$

and confined core properties:

$$b = 90.00$$

$$d = 227.00$$

$$d' = 13.00$$

$$fcc (5A.2, \text{TBDY}) = 20.00$$

$$cc (5A.5, \text{TBDY}) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 1.67441$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 1.67441$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 3.65636$$

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)

---->
 $v < v_{s,y1}$ - LHS eq.(4.7) is not satisfied

---->
 $v < v_{c,y1}$ - RHS eq.(4.6) is not satisfied

---->
 ϕ_{cu} (4.11) = 0.69203654
 M_{Rc} (4.18) = 1.9359E+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, ϕ_1, ϕ_2, v normalised to $b_o d_o$, instead of $b d$
- ϕ_1, ϕ_2, v parameters of confined concrete, $\phi_{cc}, \phi_{cc}, v_{cc}$, used in lieu of ϕ_c, ϕ_c, v_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

---->
 ϕ^*_{cu} (4.11) = 0.73305448
 M_{Ro} (4.18) = 1.3270E+008

$M_{Ro} < 0.8 M_{Rc}$

---->
 $\phi_u = \phi_{cu}$ (unconfined full section) = 1.9679130E-005
 $M_u = M_{Rc}$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of M_{u2+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.9679130E-005$

$M_u = 1.9359E+008$

with full section properties:

$b = 150.00$

$d = 257.00$

$d' = 43.00$

$v = 1.29793$

$N = 1.0007E+006$

$f_c = 20.00$

ϕ_{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

$ase = \text{Max}(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.00$

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.

$Aconf,max = 35100.00$ is the 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.

$AnoConf = 16650.00$ is the unconfined core area which is equal to $bi^2/6$ as defined at (A.2).

$psh,min = \text{Min}(psh,x, psh,y) = 0.00404182$

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) = $Lstir * Astir / (Asec * s) = 0.00404182$

$Lstir$ (Length of stirrups along Y) = 660.00

$Astir$ (stirrups area) = 78.53982

$Asec$ (section area) = 67500.00

 psh,y ((5.4d), TBDY) = $Lstir * Astir / (Asec * s) = 0.00404182$

$Lstir$ (Length of stirrups along X) = 660.00

$Astir$ (stirrups area) = 78.53982

$Asec$ (section area) = 67500.00

 $s = 190.00$

$fywe = 555.55$

$fce = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.002$

$c = \text{confinement factor} = 1.00$

$y1 = 0.00231479$

$sh1 = 0.008$

$ft1 = 666.66$

$fy1 = 555.55$

$su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/d = 1.00$

$su1 = 0.4 * esu1_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, 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 $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs2 = fs = 555.55$

with $Es2 = Es = 200000.00$

$yv = 0.00231479$
 $shv = 0.008$
 $ftv = 666.66$
 $fyv = 555.55$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 1.00$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv,ftv,fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1,ft1,fy1$, are also multiplied by $Min(1,1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = fs = 555.55$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.88736994$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.88736994$
 $v = Asl,mid/(b*d)*(fsv/fc) = 1.93773$
 and confined core properties:
 $b = 90.00$
 $d = 227.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c =$ confinement factor $= 1.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 1.67441$
 $2 = Asl,com/(b*d)*(fs2/fc) = 1.67441$
 $v = Asl,mid/(b*d)*(fsv/fc) = 3.65636$
 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
 --->
 $cu (4.11) = 0.69203654$
 $MRC (4.18) = 1.9359E+008$
 --->
 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) = 0.73305448
MRo (4.18) = 1.3270E+008
MRo < 0.8*MRc

--->
u = cu (unconfined full section) = 1.9679130E-005
Mu = MRc

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.9679130E-005
Mu = 1.9359E+008

with full section properties:

b = 150.00
d = 257.00
d' = 43.00
v = 1.29793
N = 1.0007E+006
fc = 20.00
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 = 35100.00 is the 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 = 16650.00 is the unconfined core area which is equal to bi²/6 as defined at (A.2).

psh,min = Min(psh,x, psh,y) = 0.00404182

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) = 0.00404182

Lstir (Length of stirrups along Y) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00404182

Lstir (Length of stirrups along X) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

s = 190.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/d = 1.00$$

$$su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, 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 $\text{Min}(1, 1.25*(lb/d)^{2/3})$, 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

$$lo/lou,min = lb/d = 1.00$$

$$suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fsv = fs = 555.55$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.88736994$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.88736994$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 1.93773$$

and confined core properties:

$$b = 90.00$$

$$d = 227.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 20.00$$

$$cc (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 1.67441$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 1.67441$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 3.65636$$

Case/Assumption: Unconfined full section - Steel rupture

' does not satisfy Eq. (4.3)

--->

v < vs,c - RHS eq.(4.5) is not satisfied

--->

Case/Assumption Rejected.

--->

New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)

--->
 $v < s, y1$ - LHS eq.(4.7) is not satisfied
--->
 $v < v_c, y1$ - RHS eq.(4.6) is not satisfied
--->

c_u (4.11) = 0.69203654
 M_{Rc} (4.18) = 1.9359E+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) = 0.73305448
 M_{Ro} (4.18) = 1.3270E+008
 $M_{Ro} < 0.8 * M_{Rc}$

--->
 $u = c_u$ (unconfined full section) = 1.9679130E-005
 $M_u = M_{Rc}$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 206387.155$

Calculation of Shear Strength at edge 1, $V_{r1} = 206387.155$
 $V_{r1} = V_{Co1}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Co1}$
 $V_{Co1} = 206387.155$
 $k_{nl} = 1$ (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)
 $f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 1446.319$
 $V_u = 5.7446150E-009$
 $d = 0.8 * h = 240.00$
 $N_u = 1.0007E+006$
 $A_g = 45000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$
where:
 $V_{s1} = 0.00$ is calculated for section web, with:
 $d = 120.00$

Av = 157079.633

fy = 444.44

s = 190.00

Vs1 is multiplied by Col1 = 0.00

s/d = 1.58333

Vs2 = 73486.813 is calculated for section flange, with:

d = 240.00

Av = 157079.633

fy = 444.44

s = 190.00

Vs2 is multiplied by Col2 = 0.83333333

s/d = 0.79166667

Vf ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: Vs + Vf <= 106950.853

bw = 150.00

Calculation of Shear Strength at edge 2, Vr2 = 206387.155

Vr2 = VCol ((10.3), ASCE 41-17) = knl*VCol0

VCol0 = 206387.155

knl = 1 (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

fc' = 20.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 0.02042443

Vu = 5.7446150E-009

d = 0.8*h = 240.00

Nu = 1.0007E+006

Ag = 45000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 73486.813

where:

Vs1 = 0.00 is calculated for section web, with:

d = 120.00

Av = 157079.633

fy = 444.44

s = 190.00

Vs1 is multiplied by Col1 = 0.00

s/d = 1.58333

Vs2 = 73486.813 is calculated for section flange, with:

d = 240.00

Av = 157079.633

fy = 444.44

s = 190.00

Vs2 is multiplied by Col2 = 0.83333333

s/d = 0.79166667

Vf ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: Vs + Vf <= 106950.853

bw = 150.00

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\phi = 0.85$
 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, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 Max Height, $H_{max} = 300.00$
 Min Height, $H_{min} = 150.00$
 Max Width, $W_{max} = 300.00$
 Min Width, $W_{min} = 150.00$
 Eccentricity, $Ecc = 75.00$
 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, $M = -22002.95$
 Shear Force, $V_2 = 38091.238$
 Shear Force, $V_3 = -16.64536$
 Axial Force, $F = -997748.352$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{st} = 0.00$
 -Compression: $A_{sc} = 5152.212$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{st,ten} = 2261.947$
 -Compression: $A_{sc,com} = 829.3805$
 -Middle: $A_{sc,mid} = 2060.885$
 Mean Diameter of Tension Reinforcement, $D_bL = 17.77778$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \phi \cdot u = 0.00505445$
 $u = y + p = 0.00594642$

- Calculation of y -

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00594642$ ((4.29), Biskinis Phd)
 $M_y = 9.2146E+007$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1321.867
 From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 6.8279E+012$
 factor = 0.70
 $A_g = 67500.00$
 $f_c' = 20.00$
 $N = 997748.352$
 $E_c \cdot I_g = 9.7541E+012$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 2.6069848E-005$
 with $f_y = 444.44$

d = 257.00
 y = 0.66832593
 A = 0.19188504
 B = 0.15171263
 with pt = 0.00404182
 pc = 0.02151441
 pv = 0.05346005
 N = 997748.352
 b = 150.00
 " = 0.16731518
 y_comp = 7.4795767E-006
 with fc = 20.00
 Ec = 21019.039
 y = 0.89100368
 A = 0.05809272
 B = 0.09347771
 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 $V_y E / V_{CoI} E = 1.14818$

d = 257.00

s = 150.00

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00404182$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 660.00$, 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 = 997748.352

$A_g = 67500.00$

$f_{cE} = 20.00$

$f_{ytE} = f_{yIE} = 444.44$

$p_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.13365012$

b = 150.00

d = 257.00

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 15

column C1, Floor 1

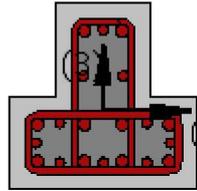
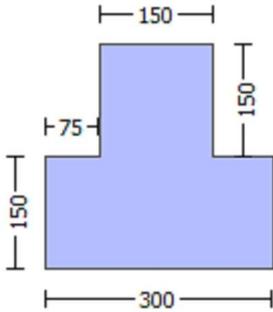
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

Max Height, $H_{max} = 300.00$

Min Height, $H_{min} = 150.00$

Max Width, $W_{max} = 300.00$

Min Width, $W_{min} = 150.00$

Eccentricity, $Ecc = 75.00$

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 ($l_o/l_{o,min} = l_b/d \geq 1$)

No FRP Wrapping

Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = -1.8497E+007$
 Shear Force, $V_a = 16.64536$
 EDGE -B-
 Bending Moment, $M_b = -22002.95$
 Shear Force, $V_b = -16.64536$
 BOTH EDGES
 Axial Force, $F = -997748.352$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{st} = 0.00$
 -Compression: $A_{sc} = 5152.212$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{st,ten} = 2261.947$
 -Compression: $A_{sc,com} = 829.3805$
 -Middle: $A_{sc,mid} = 2060.885$
 Mean Diameter of Tension Reinforcement, $D_{bL,ten} = 17.77778$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 109306.383$
 V_n ((10.3), ASCE 41-17) = $k_n l * V_{CoIO} = 128595.745$
 $V_{CoI} = 128595.745$
 $k_n l = 1.00$
 $displacement_ductility_demand = 0.12249231$

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+} + \phi V_f$ '
 where V_f is the contribution of FRPs ((11.3), ACI 440).

= 1 (normal-weight concrete)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa ((22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 22002.95$
 $V_u = 16.64536$
 $d = 0.8 * h = 240.00$
 $N_u = 997748.352$
 $A_g = 45000.00$
 From ((11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 66138.793$
 where:
 $V_{s1} = 66138.793$ is calculated for section web, with:
 $d = 240.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 190.00$
 V_{s1} is multiplied by $Col1 = 0.83333333$
 $s/d = 0.79166667$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 120.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 190.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.58333$
 V_f ((11-3)-(11.4), ACI 440) = 0.00
 From ((11-11), ACI 440: $V_s + V_f \leq 95659.751$
 $bw = 150.00$

$displacement_ductility_demand$ is calculated as ϕ / y

- Calculation of ϕ / y for END B -
 for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\phi = 0.00072839$
 $y = (M_y * L_s / 3) / E_{eff} = 0.00594642$ ((4.29), Biskinis Phd))

My = 9.2146E+007
Ls = M/V (with Ls > 0.1*L and Ls < 2*L) = 1321.867
From table 10.5, ASCE 41_17: Eleff = factor*Ec*Ig = 6.8279E+012
factor = 0.70
Ag = 67500.00
fc' = 20.00
N = 997748.352
Ec*Ig = 9.7541E+012

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

y = Min(y_ten, y_com)
y_ten = 2.6069848E-005
with fy = 444.44
d = 257.00
y = 0.66832593
A = 0.19188504
B = 0.15171263
with pt = 0.05867566
pc = 0.02151441
pv = 0.05346005
N = 997748.352
b = 150.00
" = 0.16731518
y_comp = 7.4795767E-006
with fc = 20.00
Ec = 21019.039
y = 0.89100368
A = 0.05809272
B = 0.09347771
with Es = 200000.00

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

End Of Calculation of Shear Capacity for element: column TC1 of floor 1
At local axis: 3
Integration Section: (b)

Calculation No. 16

column C1, Floor 1

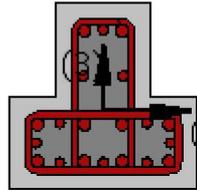
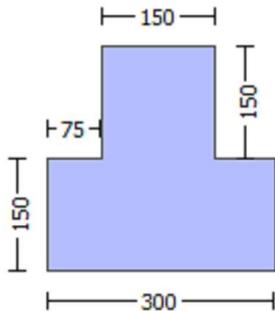
Limit State: Life Safety (data interpolation between analysis steps 50 and 51)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_u)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height, $H_{max} = 300.00$

Min Height, $H_{min} = 150.00$

Max Width, $W_{max} = 300.00$

Min Width, $W_{min} = 150.00$

Eccentricity, $E_{cc} = 75.00$

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, $V_a = -1.1623543E-006$

EDGE -B-

Shear Force, $V_b = 1.1623543E-006$

BOTH EDGES

Axial Force, $F = -1.0007E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{s,ten} = 2261.947$

-Compression: $A_{s,com} = 829.3805$

-Middle: $A_{s,mid} = 2060.885$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.14818$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 160672.713$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.4101E+008$

$M_{u1+} = 1.4763E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.4101E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.4101E+008$

$M_{u2+} = 1.4763E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 2.4101E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of M_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.6767311E-005$

$M_u = 1.4763E+008$

with full section properties:

$b = 150.00$

$d = 257.00$

$d' = 43.00$

$v = 1.29793$

$N = 1.0007E+006$

$f_c = 20.00$

$\alpha = 0.002$ (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: $\phi_u = 0.0035$

$\phi_{ue} = 0.00$

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.00$

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00404182$

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)

$$\text{psh}_x \text{ ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00404182$$

$$\text{Lstir (Length of stirrups along Y)} = 660.00$$

$$\text{Astir (stirrups area)} = 78.53982$$

$$\text{Asec (section area)} = 67500.00$$

$$\text{psh}_y \text{ ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00404182$$

$$\text{Lstir (Length of stirrups along X)} = 660.00$$

$$\text{Astir (stirrups area)} = 78.53982$$

$$\text{Asec (section area)} = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, 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

$$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$$

$$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs_2 = fs = 555.55$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00231479$$

$$sh_v = 0.008$$

$$ft_v = 666.66$$

$$fy_v = 555.55$$

$$su_v = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

$$su_v = 0.4 * esu_{v,nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu_{v,nominal} = 0.08$,

considering characteristic value $fsy_v = fs_v/1.2$, from table 5.1, TBDY

For calculation of $esu_{v,nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsy_v = fs_v/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs_v = fs = 555.55$$

$$\text{with } Es_v = Es = 200000.00$$

$$1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 1.62986$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.59761649$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 1.48499$$

and confined core properties:

$$b = 90.00$$

$$d = 227.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 20.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 3.07544$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 1.12766$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 2.80207$$

Case/Assumption: Unconfined full section - Steel rupture

' does not satisfy Eq. (4.3)

$v < v_{s,c}$ - RHS eq.(4.5) is not satisfied

Case/Assumption Rejected.

New Case/Assumption: Unconfined full section - Spalling of concrete cover

' satisfies Eq. (4.4)

$v < s_{y1}$ - LHS eq.(4.7) is not satisfied

$v < v_{c,y1}$ - RHS eq.(4.6) is not satisfied

$$c_u (4.11) = 0.81221594$$

$$MR_c (4.18) = 1.4763E+008$$

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} , c_c , used in lieu of f_c , c_u

Subcase: Rupture of tension steel

$v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

$v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

Subcase rejected

New Subcase: Failure of compression zone

$v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

$v^* < v^*_{c,y1}$ - RHS eq.(4.6) is not satisfied

$$*c_u (4.11) = 0.91366546$$

$$MR_o (4.18) = 8.4535E+007$$

$$MR_o < 0.8*MR_c$$

$$u = c_u (\text{unconfined full section}) = 1.6767311E-005$$

$$M_u = MR_c$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of M_{u1} -

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 1.8792920E-005$$

$$\mu = 2.4101E+008$$

with full section properties:

$$b = 300.00$$

$$d = 257.00$$

$$d' = 43.00$$

$$v = 0.64896668$$

$$N = 1.0007E+006$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0035$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.0035$$

$$\phi_{we} \text{ (5.4c)} = 0.00$$

$$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00404182$$

Expression ((5.4d), TBDY) for $\phi_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\phi_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 660.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 67500.00$$

$$\phi_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along X)} = 660.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{1,nominal} = 0.08,$$

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1 / 1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$, from 10.3.5, 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/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) = 0.29880825
2 = Asl,com/(b*d)*(fs2/fc) = 0.81493158
v = Asl,mid/(b*d)*(fsv/fc) = 0.74249322
and confined core properties:
b = 240.00
d = 227.00
d' = 13.00
fcc (5A.2, TBDY) = 20.00
cc (5A.5, TBDY) = 0.002
c = confinement factor = 1.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.4228729
2 = Asl,com/(b*d)*(fs2/fc) = 1.15329
v = Asl,mid/(b*d)*(fsv/fc) = 1.05078
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) = 0.45266836
MRc (4.17) = 2.7366E+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) = 0.46882405

MRo (4.18) = 2.4101E+008

--->

u = cu (4.2) = 1.8792920E-005

Mu = MRo

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.6767311E-005

Mu = 1.4763E+008

with full section properties:

b = 150.00

d = 257.00

d' = 43.00

v = 1.29793

N = 1.0007E+006

fc = 20.00

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 = 35100.00 is the 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 = 16650.00 is the unconfined core area which is equal to bi²/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00404182

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) = 0.00404182

Lstir (Length of stirrups along Y) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00404182

Lstir (Length of stirrups along X) = 660.00
Astir (stirrups area) = 78.53982
Asec (section area) = 67500.00

s = 190.00

fywe = 555.55

fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, 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) = 1.62986

2 = Asl,com/(b*d)*(fs2/fc) = 0.59761649

v = Asl,mid/(b*d)*(fsv/fc) = 1.48499

and confined core properties:

b = 90.00

d = 227.00

d' = 13.00

fcc (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00
1 = $A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 3.07544$
2 = $A_{sl,com}/(b*d)*(f_{s2}/f_c) = 1.12766$
v = $A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 2.80207$

Case/Assumption: Unconfined full section - Steel rupture
' does not satisfy Eq. (4.3)

---->
v < v_{s,c} - RHS eq.(4.5) is not satisfied

---->
Case/Assumption Rejected.

---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)

---->
v < s_{y1} - LHS eq.(4.7) is not satisfied

---->
v < v_{c,y1} - RHS eq.(4.6) is not satisfied

---->
c_u (4.11) = 0.81221594
MR_c (4.18) = 1.4763E+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_{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) = 0.91366546
MR_o (4.18) = 8.4535E+007

MR_o < 0.8*MR_c

---->
u = c_u (unconfined full section) = 1.6767311E-005
Mu = MR_c

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 = 1.8792920E-005

Mu = 2.4101E+008

with full section properties:

b = 300.00

d = 257.00

d' = 43.00

$$v = 0.64896668$$

$$N = 1.0007E+006$$

$$f_c = 20.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0035$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0035$$

$$w_e (5.4c) = 0.00$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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., 10.11061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} (\text{Length of stirrups along Y}) = 660.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 67500.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} (\text{Length of stirrups along X}) = 660.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{1,nominal} = 0.08,$$

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, 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

$$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$$

$$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{2,nominal} = 0.08,$$

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered

characteristic value $f_{s2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, 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 $E_{s2} = E_s = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$s_{uv} = 0.032$

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

$l_o/l_{o,min} = l_b/l_d = 1.00$

$s_{uv} = 0.4 \cdot e_{suv_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $e_{suv_nominal} = 0.08$,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $f_{sv} = f_s = 555.55$

with $E_{sv} = E_s = 200000.00$

1 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.29880825$

2 = $A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.81493158$

$v = A_{s1,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.74249322$

and confined core properties:

$b = 240.00$

$d = 227.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 20.00$

$cc (5A.5, TBDY) = 0.002$

$c = \text{confinement factor} = 1.00$

1 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.4228729$

2 = $A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 1.15329$

$v = A_{s1,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 1.05078$

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

$c_u (4.10) = 0.45266836$

$M_{Rc} (4.17) = 2.7366E+008$

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

--->

*cu (4.11) = 0.46882405

M_{Ro} (4.18) = 2.4101E+008

--->

u = cu (4.2) = 1.8792920E-005

Mu = M_{Ro}

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 139936.984$

Calculation of Shear Strength at edge 1, $V_{r1} = 139936.984$

$V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = knl*V_{Col0}

V_{Col0} = 139936.984

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)

fc' = 20.00, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 934188.794

Vu = 1.1623543E-006

d = 0.8*h = 240.00

Nu = 1.0007E+006

Ag = 45000.00

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

$V_{s1} = 73486.813$ is calculated for section web, with:

d = 240.00

Av = 157079.633

fy = 444.44

s = 190.00

V_{s1} is multiplied by Col1 = 0.83333333

s/d = 0.79166667

$V_{s2} = 0.00$ is calculated for section flange, with:

d = 120.00

Av = 157079.633

fy = 444.44

s = 190.00

V_{s2} is multiplied by Col2 = 0.00

s/d = 1.58333

V_f ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: $V_s + V_f \leq 106950.853$

bw = 150.00

Calculation of Shear Strength at edge 2, $V_{r2} = 139936.984$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = knl*V_{Col0}

V_{Col0} = 139936.984

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)

fc' = 20.00, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$
 $\mu_u = 760.756$
 $V_u = 1.1623543E-006$
 $d = 0.8 \cdot h = 240.00$
 $N_u = 1.0007E+006$
 $A_g = 45000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$
 where:
 $V_{s1} = 73486.813$ is calculated for section web, with:
 $d = 240.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 190.00$
 V_{s1} is multiplied by $Col1 = 0.83333333$
 $s/d = 0.79166667$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 120.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 190.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.58333$
 $V_f ((11-3)-(11.4), ACI 440) = 0.00$
 From (11-11), ACI 440: $V_s + V_f \leq 106950.853$
 $b_w = 150.00$

 End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
 At local axis: 3

 Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rctcs

Constant Properties

 Knowledge Factor, $\phi = 0.85$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$
 #####
 Max Height, $H_{max} = 300.00$
 Min Height, $H_{min} = 150.00$
 Max Width, $W_{max} = 300.00$
 Min Width, $W_{min} = 150.00$
 Eccentricity, $Ecc = 75.00$
 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, $V_a = -5.7446150E-009$

EDGE -B-

Shear Force, $V_b = 5.7446150E-009$

BOTH EDGES

Axial Force, $F = -1.0007E+006$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1231.504$

-Compression: $As_{c,com} = 1231.504$

-Middle: $As_{l,mid} = 2689.203$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.62533189$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 129060.47$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.9359E+008$

$Mu_{1+} = 1.9359E+008$, 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

$Mu_{1-} = 1.9359E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.9359E+008$

$Mu_{2+} = 1.9359E+008$, 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

$Mu_{2-} = 1.9359E+008$, 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:

$\phi_u = 1.9679130E-005$

$M_u = 1.9359E+008$

with full section properties:

$b = 150.00$

$d = 257.00$

$d' = 43.00$

$v = 1.29793$

$N = 1.0007E+006$

$f_c = 20.00$

ω (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0035$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.0035$

ω_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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$

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)

 $p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along Y) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

 $p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$

L_{stir} (Length of stirrups along X) = 660.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 67500.00

 $s = 190.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.002$

$c = \text{confinement factor} = 1.00$

$y_1 = 0.00231479$

$sh_1 = 0.008$

$ft_1 = 666.66$

$fy_1 = 555.55$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = fs = 555.55$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00231479$

$sh_2 = 0.008$

$ft_2 = 666.66$

$fy_2 = 555.55$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_2 = fs = 555.55$

with $Es_2 = Es = 200000.00$

$y_v = 0.00231479$

$sh_v = 0.008$

$ft_v = 666.66$

$fy_v = 555.55$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$su_v = 0.4 * esu_{v,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu_{v,nominal} = 0.08$,

considering characteristic value $fsy_v = fs_v/1.2$, from table 5.1, TBDY

For calculation of $esu_{v,nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $f_{sv} = f_s = 555.55$

with $E_{sv} = E_s = 200000.00$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.88736994$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.88736994$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 1.93773$

and confined core properties:

$b = 90.00$

$d = 227.00$

$d' = 13.00$

f_{cc} (5A.2, TBDY) = 20.00

cc (5A.5, TBDY) = 0.002

c = confinement factor = 1.00

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 1.67441$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 1.67441$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 3.65636$

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

--->

$\ast cu$ (4.11) = 0.69203654

M_{Rc} (4.18) = 1.9359E+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, 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

--->

$\ast cu$ (4.11) = 0.73305448

M_{Ro} (4.18) = 1.3270E+008

$M_{Ro} < 0.8 \cdot M_{Rc}$

--->

$u = cu$ (unconfined full section) = 1.9679130E-005

$M_u = M_{Rc}$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Mu1-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.9679130E-005$$

$$Mu = 1.9359E+008$$

with full section properties:

$$b = 150.00$$

$$d = 257.00$$

$$d' = 43.00$$

$$v = 1.29793$$

$$N = 1.0007E+006$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0035$$

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.

$A_{conf,max} = 35100.00$ is the 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.

$A_{noConf} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00404182$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 660.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 67500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00404182$$

$$L_{stir} \text{ (Length of stirrups along X)} = 660.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 67500.00$$

$$s = 190.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y_1 = 0.00231479$$

$$sh_1 = 0.008$$

$$ft_1 = 666.66$$

$$fy_1 = 555.55$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/d = 1.00$$

$$su_1 = 0.4 * esu_1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu_1_{nominal} = 0.08$,

For calculation of $esu_1_{nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs_1 = fs = 555.55$$

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
 $lo/lo_{min} = lb/lb_{min} = 1.00$
 $su_2 = 0.4 * esu_{2_nominal} ((5.5), TBDY) = 0.032$
 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 $fs_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_2 = fs = 555.55$
 with $E_s2 = E_s = 200000.00$
 $y_v = 0.00231479$
 $sh_v = 0.008$
 $ft_v = 666.66$
 $fy_v = 555.55$
 $su_v = 0.032$
 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
 $lo/lo_{min} = lb/d = 1.00$
 $su_v = 0.4 * esu_{v_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{v_nominal} = 0.08$,
 considering characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY
 For calculation of $esu_{v_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_v = fs = 555.55$
 with $E_{sv} = E_s = 200000.00$
 $1 = As_{l,ten}/(b*d) * (fs_1/f_c) = 0.88736994$
 $2 = As_{l,com}/(b*d) * (fs_2/f_c) = 0.88736994$
 $v = As_{l,mid}/(b*d) * (fs_v/f_c) = 1.93773$
 and confined core properties:
 $b = 90.00$
 $d = 227.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = As_{l,ten}/(b*d) * (fs_1/f_c) = 1.67441$
 $2 = As_{l,com}/(b*d) * (fs_2/f_c) = 1.67441$
 $v = As_{l,mid}/(b*d) * (fs_v/f_c) = 3.65636$
 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
 --->
 $cu (4.11) = 0.69203654$
 $M_{Rc} (4.18) = 1.9359E+008$
 --->
 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 $b_0 \cdot d_0$, instead of $b \cdot d$
- parameters of confined concrete, f_{cc} , c_c , used in lieu of f_c , e_{cu}

---->

Subcase: Rupture of tension steel

---->

$v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->

$v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

---->

Subcase rejected

---->

New Subcase: Failure of compression zone

---->

$v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

---->

$v^* < v^*_{c,y1}$ - RHS eq.(4.6) is not satisfied

---->

* c_u (4.11) = 0.73305448

M R_o (4.18) = 1.3270E+008

M $R_o < 0.8 \cdot M_{Rc}$

---->

u = c_u (unconfined full section) = 1.9679130E-005

Mu = M R_c

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Mu2+

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

u = 1.9679130E-005

Mu = 1.9359E+008

with full section properties:

b = 150.00

d = 257.00

d' = 43.00

v = 1.29793

N = 1.0007E+006

f c = 20.00

c_o (5A.5, TBDY) = 0.002

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)

From (5.4b), TBDY: $c_u = 0.0035$

w e (5.4c) = 0.00

ase = $\text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) \cdot (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$

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.

$A_{\text{conf,max}} = 35100.00$ is the 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.

$A_{\text{noConf}} = 16650.00$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

psh,min = $\text{Min}(psh_x, psh_y) = 0.00404182$

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)

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00404182$$

$$Lstir (\text{Length of stirrups along } Y) = 660.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 67500.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00404182$$

$$Lstir (\text{Length of stirrups along } X) = 660.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 67500.00$$

$$s = 190.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$y1 = 0.00231479$$

$$sh1 = 0.008$$

$$ft1 = 666.66$$

$$fy1 = 555.55$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/ld = 1.00$$

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_nominal = 0.08,$$

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

$$y1, sh1,ft1,fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs1 = fs = 555.55$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00231479$$

$$sh2 = 0.008$$

$$ft2 = 666.66$$

$$fy2 = 555.55$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 1.00$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_nominal = 0.08,$$

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

$$y2, sh2,ft2,fy2, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs2 = fs = 555.55$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00231479$$

$$shv = 0.008$$

$$ftv = 666.66$$

$$fyv = 555.55$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/ld = 1.00$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esuv_nominal = 0.08,$$

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

$$yv, shv,ftv,fyv, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fsv = fs = 555.55$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.88736994$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.88736994$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 1.93773$$

and confined core properties:

$$b = 90.00$$

$$d = 227.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 20.00$$

$$cc (5A.5, TBDY) = 0.002$$

$$c = \text{confinement factor} = 1.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 1.67441$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 1.67441$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 3.65636$$

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

$$cu (4.11) = 0.69203654$$

$$MRc (4.18) = 1.9359E+008$$

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 $b*d$

- f_{cc} , f_{cc} , f_{cc} parameters of confined concrete, f_{cc} , f_{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

$$*cu (4.11) = 0.73305448$$

$$MRo (4.18) = 1.3270E+008$$

$$MRo < 0.8*MRc$$

$$u = cu (\text{unconfined full section}) = 1.9679130E-005$$

$$Mu = MRc$$

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:

$$u = 1.9679130E-005$$

Mu = 1.9359E+008

with full section properties:

b = 150.00

d = 257.00

d' = 43.00

v = 1.29793

N = 1.0007E+006

fc = 20.00

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 = 35100.00 is the 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 = 16650.00 is the unconfined core area which is equal to bi²/6 as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00404182

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) = 0.00404182

Lstir (Length of stirrups along Y) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00404182

Lstir (Length of stirrups along X) = 660.00

Astir (stirrups area) = 78.53982

Asec (section area) = 67500.00

s = 190.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.002

c = confinement factor = 1.00

y1 = 0.00231479

sh1 = 0.008

ft1 = 666.66

fy1 = 555.55

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)²/3), from 10.3.5, 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
 $l_o/l_{o,min} = l_b/l_{b,min} = 1.00$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, 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
 $l_o/l_{o,min} = l_b/l_d = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
considering characteristic value $fsy_v = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsy_v = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
with $fsv = fs = 555.55$
with $Es_v = Es = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/fc) = 0.88736994$
 $2 = A_{sl,com}/(b*d) * (fs_2/fc) = 0.88736994$
 $v = A_{sl,mid}/(b*d) * (fsv/fc) = 1.93773$
and confined core properties:
 $b = 90.00$
 $d = 227.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 $c = \text{confinement factor} = 1.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/fc) = 1.67441$
 $2 = A_{sl,com}/(b*d) * (fs_2/fc) = 1.67441$
 $v = A_{sl,mid}/(b*d) * (fsv/fc) = 3.65636$
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
---->
 $cu (4.11) = 0.69203654$
 $M_{Rc} (4.18) = 1.9359E+008$
---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: $bo, do, d'o$
- $N, 1, 2, v$ normalised to $bo*do$, instead of $b*d$
- - parameters of confined concrete, f_{cc}, cc , used in lieu of f_c, 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

--->

ϕ_{cu} (4.11) = 0.73305448

M_{Ro} (4.18) = 1.3270E+008

$M_{Ro} < 0.8 \cdot M_{Rc}$

--->

$u = \phi_{cu}$ (unconfined full section) = 1.9679130E-005

$\mu = M_{Rc}$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 206387.155$

Calculation of Shear Strength at edge 1, $V_{r1} = 206387.155$

$V_{r1} = V_{Co1}$ ((10.3), ASCE 41-17) = $k_n l \cdot V_{Co10}$

$V_{Co10} = 206387.155$

$k_n l = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + \phi \cdot V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

 $\phi = 1$ (normal-weight concrete)

$f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu = 1446.319$

$V_u = 5.7446150E-009$

$d = 0.8 \cdot h = 240.00$

$N_u = 1.0007E+006$

$A_g = 45000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 120.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 190.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 1.58333$

$V_{s2} = 73486.813$ is calculated for section flange, with:

$d = 240.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 190.00$

V_{s2} is multiplied by $Col2 = 0.833333333$

$s/d = 0.79166667$

V_f ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: $V_s + V_f \leq 106950.853$

$b_w = 150.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 206387.155$

$V_{r2} = V_{Co2}$ ((10.3), ASCE 41-17) = $k_n l \cdot V_{Co20}$

$V_{Co20} = 206387.155$

knl = 1 (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

fc' = 20.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 0.02042443

Vu = 5.7446150E-009

d = 0.8*h = 240.00

Nu = 1.0007E+006

Ag = 45000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 73486.813

where:

Vs1 = 0.00 is calculated for section web, with:

d = 120.00

Av = 157079.633

fy = 444.44

s = 190.00

Vs1 is multiplied by Col1 = 0.00

s/d = 1.58333

Vs2 = 73486.813 is calculated for section flange, with:

d = 240.00

Av = 157079.633

fy = 444.44

s = 190.00

Vs2 is multiplied by Col2 = 0.83333333

s/d = 0.79166667

Vf ((11-3)-(11.4), ACI 440) = 0.00

From (11-11), ACI 440: Vs + Vf <= 106950.853

bw = 150.00

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1
At local axis: 3
Integration Section: (b)
Section Type: rctcs

Constant Properties

Knowledge Factor, = 0.85

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 = 20.00

Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44

Concrete Elasticity, Ec = 21019.039

Steel Elasticity, Es = 200000.00

Max Height, Hmax = 300.00

Min Height, Hmin = 150.00

Max Width, Wmax = 300.00

Min Width, Wmin = 150.00

Eccentricity, Ecc = 75.00

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, $M = -7.6430E+006$
Shear Force, $V2 = 38091.238$
Shear Force, $V3 = -16.64536$
Axial Force, $F = -997748.352$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 5152.212$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{s,ten} = 1231.504$
-Compression: $A_{s,com} = 1231.504$
-Middle: $A_{s,mid} = 2689.203$
Mean Diameter of Tension Reinforcement, $D_bL = 17.60$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = * u = 0.00167931$
 $u = y + p = 0.00197566$

- Calculation of y -

 $y = (M_y * L_s / 3) / E_{eff} = 0.00197566$ ((4.29), Biskinis Phd)
 $M_y = 1.1037E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 5.5865E+012$
factor = 0.70
 $A_g = 67500.00$
 $f_c' = 20.00$
 $N = 997748.352$
 $E_c * I_g = 7.9807E+012$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

 $y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 2.2090882E-005$
with $f_y = 444.44$
 $d = 257.00$
 $y = 0.60858546$
 $A = 0.19188504$
 $B = 0.13624083$
with $p_t = 0.00404182$
 $p_c = 0.03194564$
 $p_v = 0.06975884$
 $N = 997748.352$
 $b = 150.00$
 $" = 0.16731518$
 $y_{comp} = 8.4879027E-006$
with $f_c = 20.00$
 $E_c = 21019.039$
 $y = 0.78515631$
 $A = 0.05809272$
 $B = 0.0780059$
with $E_s = 200000.00$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

- Calculation of ρ -

From table 10-8: $\rho = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$
shear control ratio $V_{yE}/V_{CoIE} = 0.62533189$

$d = 257.00$

$s = 150.00$

$t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.00404182$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 660.00$, 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.

$NUD = 997748.352$

$A_g = 67500.00$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 444.44$

$\rho_l = \text{Area_Tot_Long_Rein}/(b*d) = 0.13365012$

$b = 150.00$

$d = 257.00$

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (b)