

Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

column C1, Floor 1

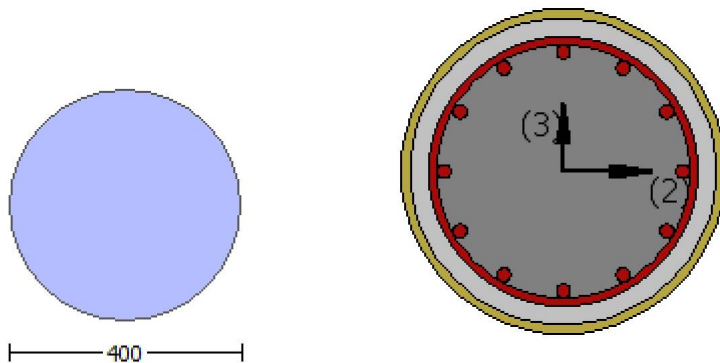
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column CC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rccs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

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

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of γ for displacement ductility demand,
 the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as
 Deformation-Controlled Action (Table C7-1, ASCE41-17).
 New material: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material: Steel Strength, $f_s = f_{sm} = 555.56$
 #####
 Diameter, $D = 400.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{ou,min} = l_b/l_d \geq 1$)
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $NoDir = 1$
 Fiber orientations, $bi: 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = -1.1282E+007$
 Shear Force, $V_a = -3759.209$
 EDGE -B-
 Bending Moment, $M_b = 0.06021356$
 Shear Force, $V_b = 3759.209$
 BOTH EDGES
 Axial Force, $F = -4769.729$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 1272.345$
 -Compression: $As_c = 1781.283$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{l,ten} = 1017.876$
 -Compression: $As_{l,com} = 1017.876$
 -Middle: $As_{l,mid} = 1017.876$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.00$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0 \cdot V_n = 330216.75$
 V_n ((10.3), ASCE 41-17) = $kn_l \cdot V_{CoIO} = 330216.75$
 $V_{CoI} = 330216.75$
 $kn_l = 1.00$
 $displacement_ductility_demand = 0.01018442$

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

$\gamma = 1$ (normal-weight concrete)
 $f'_c = 25.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 1.1282E+007$
 $V_u = 3759.209$
 $d = 0.8 \cdot D = 320.00$

$N_u = 4769.729$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 197392.088$
 $A_v = \frac{1}{2} A_{stirrup} = 123370.055$
 $f_y = 500.00$
 $s = 100.00$
 V_s is multiplied by $\text{Col} = 0.00$
 $s/d = 0.3125$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 194961.134$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $tf_1 = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 370.00
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 267132.42$
 $bw \cdot d = \frac{1}{4} \cdot d \cdot d = 80424.772$

displacement_ductility_demand is calculated as δ / y

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

From analysis, chord rotation $\theta = 0.00030347$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.02979765$ ((4.29), Biskinis Phd))
 $M_y = 3.0318E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 3001.151
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 1.0179E+013$
 $\text{factor} = 0.30$
 $A_g = 125663.706$
 $f_c' = 33.00$
 $N = 4769.729$
 $E_c \cdot I_g = 3.3929E+013$

Calculation of Yielding Moment M_y

Calculation of δ and M_y according to (7) - (8) in Biskinis and Fardis

$M_y = \text{Min}(M_{y_ten}, M_{y_com}) = 3.0318E+008$
 $y ((10a) \text{ or } (10b)) = 1.6222680E-005$
 $M_{y_ten} (8a) = 3.0318E+008$
 $\delta_{ten} (7a) = 69.35397$
 error of function (7a) = 0.00743258
 $M_{y_com} (8b) = 4.6746E+008$
 $\delta_{com} (7b) = 67.1564$
 error of function (7b) = -0.00265541
 with $e_y = 0.0027778$
 $e_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00102226$
 $N = 4769.729$
 $A_c = 125663.706$
 $= 0.36359274$

with f_c^* ((12.3), ACI 440) = 37.12975
 $f_c = 33.00$
 $f_l = 1.3173$
 $k = 1$
Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $E_f = 64828.00$

Calculation of ratio I_b/I_d

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

End Of Calculation of Shear Capacity for element: column CC1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 2

column C1, Floor 1

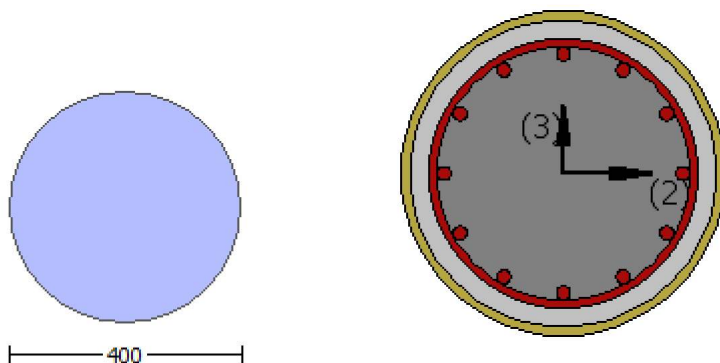
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ)

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rccs

Constant Properties

Knowledge Factor, $\phi = 0.90$

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

Consequently:

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

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New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$ 
Concrete Elasticity,  $E_c = 26999.444$ 
Steel Elasticity,  $E_s = 200000.00$ 
#####
Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$ 
#####
Diameter,  $D = 400.00$ 
Cover Thickness,  $c = 25.00$ 
Mean Confinement Factor overall section = 1.56406
Element Length,  $L = 3000.00$ 
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ( $l_o/l_{ou}, \min > = 1$ )
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $\epsilon_{fu} = 0.01$ 
Number of directions,  $N_{oDir} = 1$ 
Fiber orientations,  $b_i: 0.00^\circ$ 
Number of layers,  $N_L = 1$ 
Radius of rounding corners,  $R = 40.00$ 
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Stepwise Properties
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At local axis: 3
EDGE -A-
Shear Force,  $V_a = 1.1167452E-031$ 
EDGE -B-
Shear Force,  $V_b = -1.1167452E-031$ 
BOTH EDGES
Axial Force,  $F = -4771.233$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
  -Tension:  $A_{slt} = 0.00$ 
  -Compression:  $A_{slc} = 3053.628$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
  -Tension:  $A_{sl,ten} = 1017.876$ 
  -Compression:  $A_{sl,com} = 1017.876$ 
  -Middle:  $A_{sl,mid} = 1017.876$ 
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Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.44725617$ 
Member Controlled by Flexure ( $V_e/V_r < 1$ )
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 202038.041$ 
with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 3.0306E+008$ 
 $\mu_{u1+} = 3.0306E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $\mu_{u1-} = 3.0306E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 3.0306E+008$ 
 $\mu_{u2+} = 3.0306E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the the static loading combination
 $\mu_{u2-} = 3.0306E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment
direction which is defined for the the static loading combination
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Calculation of Mu1+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02
From 5A.2, TDY: fcc = fc* c = 51.61391
conf. factor c = 1.56406
fc = 33.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 694.45
lb/d = 1.00
d1 = 44.00
R = 200.00
v = 0.00101663
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.45184585

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02
From 5A.2, TDY: fcc = fc* c = 51.61391
conf. factor c = 1.56406
fc = 33.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 694.45
lb/d = 1.00
d1 = 44.00
R = 200.00
v = 0.00101663
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.45184585

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974
' = 0.91217079

error of function (3.68), Biskinis Phd = 60360.02
 From 5A.2, TBDY: $f_{cc} = f_c' \cdot c = 51.61391$
 conf. factor $c = 1.56406$
 $f_c = 33.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/d

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

Calculation of μ_2 -

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 3.0306E+008$

$= 1.02974$
 $' = 0.91217079$
 error of function (3.68), Biskinis Phd = 60360.02
 From 5A.2, TBDY: $f_{cc} = f_c' \cdot c = 51.61391$
 conf. factor $c = 1.56406$
 $f_c = 33.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 451727.786$

Calculation of Shear Strength at edge 1, $V_{r1} = 451727.786$

$V_{r1} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = k_{nl} \cdot V_{CoIO}$
 $V_{CoIO} = 451727.786$
 $k_{nl} = 1$ (zero step-static loading)

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

$= 1$ (normal-weight concrete)
 $f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu = 1.5353150E-011$
 $V_u = 1.1167452E-031$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$

$A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 219326.297$
 $A_v = \frac{1}{2} A_{stirrup} = 123370.055$
 $f_y = 555.56$
 $s = 100.00$
 V_s is multiplied by $Col = 0.00$
 $s/d = 0.3125$
 $V_f ((11-3)-(11.4), ACI 440) = 194961.134$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(,)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $tf_1 = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 370.00
 $f_{fe} ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 306911.784$
 $b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 451727.786$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{ColO}$
 $V_{ColO} = 451727.786$
 $knl = 1$ (zero step-static loading)

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

$\beta = 1$ (normal-weight concrete)
 $f'_c = 33.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 1.5353150E-011$
 $V_u = 1.1167452E-031$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 219326.297$
 $A_v = \frac{1}{2} A_{stirrup} = 123370.055$
 $f_y = 555.56$
 $s = 100.00$
 V_s is multiplied by $Col = 0.00$
 $s/d = 0.3125$
 $V_f ((11-3)-(11.4), ACI 440) = 194961.134$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(,)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $tf_1 = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 370.00
 $f_{fe} ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 306911.784$
 $b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 80424.772$

End Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rccs

Constant Properties

Knowledge Factor, $\gamma = 0.90$
Mean strength values are used for both shear and moment calculations.
Consequently:
New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

Diameter, $D = 400.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.56406
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou}, \min \geq 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $\epsilon_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = -6.8378665E-048$
EDGE -B-
Shear Force, $V_b = 6.8378665E-048$
BOTH EDGES
Axial Force, $F = -4771.233$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 3053.628$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1017.876$
-Compression: $As_{l,com} = 1017.876$
-Middle: $As_{l,mid} = 1017.876$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.44725617$
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 202038.041$
 with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 3.0306E+008$
 $\mu_{u1+} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
 which is defined for the static loading combination
 $\mu_{u1-} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
 direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 3.0306E+008$
 $\mu_{u2+} = 3.0306E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
 which is defined for the the static loading combination
 $\mu_{u2-} = 3.0306E+008$, 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 Moment Strength ((3.67), Biskinis Phd), μ_u
 $\mu_u = 3.0306E+008$

$\phi = 1.02974$
 $\lambda = 0.91217079$
 error of function (3.68), Biskinis Phd = 60360.02
 From 5A.2, TB DY: $f_{cc} = f_c^* \quad c = 51.61391$
 conf. factor $c = 1.56406$
 $f_c = 33.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \phi \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/d

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

Calculation of μ_{u1-}

 Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ_u
 $\mu_u = 3.0306E+008$

$\phi = 1.02974$
 $\lambda = 0.91217079$
 error of function (3.68), Biskinis Phd = 60360.02
 From 5A.2, TB DY: $f_{cc} = f_c^* \quad c = 51.61391$
 conf. factor $c = 1.56406$
 $f_c = 33.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \phi \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/d

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

Calculation of μ_{2+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 3.0306E+008$

$$= 1.02974$$

$$' = 0.91217079$$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 51.61391$

conf. factor $c = 1.56406$

$$f_c = 33.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00101663$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of μ_{2-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 3.0306E+008$

$$= 1.02974$$

$$' = 0.91217079$$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 51.61391$

conf. factor $c = 1.56406$

$$f_c = 33.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00101663$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 451727.786$

Calculation of Shear Strength at edge 1, $V_{r1} = 451727.786$

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

$V_{Col0} = 451727.786$

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

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

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

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

$M/Vd = 2.00$

$\mu_u = 5.4715235E-012$

$\nu_u = 6.8378665E-048$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 219326.297$

$A_v = \frac{1}{2} \cdot A_{stirrup} = 123370.055$

$f_y = 555.56$

$s = 100.00$

V_s is multiplied by $Col = 0.00$

$s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 194961.134

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,

where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \min(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_{fe} = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 306911.784$

$b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 451727.786$

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

$V_{Col0} = 451727.786$

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

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

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

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

$M/Vd = 2.00$

$\mu_u = 5.4715235E-012$

$\nu_u = 6.8378665E-048$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 219326.297$

$A_v = \frac{1}{2} \cdot A_{stirrup} = 123370.055$

$f_y = 555.56$

$s = 100.00$

V_s is multiplied by $Col = 0.00$

$s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 194961.134

$f = 0.95$, for fully-wrapped sections

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:

total thickness per orientation, $t_{f1} = NL * t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

$f_{fe}((11-5), \text{ACI 440}) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 306911.784$

$b_w * d = \rho_s * d * d / 4 = 80424.772$

End Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column CC1 of floor 1
At local axis: 2

Integration Section: (a)

Section Type: rccs

Constant Properties

Knowledge Factor, $\phi = 0.90$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $\text{NoDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 6.3952987E-010$

Shear Force, $V_2 = -3759.209$

Shear Force, $V_3 = -1.9910600E-013$

Axial Force, $F = -4769.729$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 1272.345$
 -Compression: $As_c = 1781.283$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{ten} = 1017.876$
 -Compression: $As_{com} = 1017.876$
 -Middle: $As_{mid} = 1017.876$
 Mean Diameter of Tension Reinforcement, $Db_L = 18.00$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = 1.0^*$ $u = 0.01989311$
 $u = y + p = 0.01989311$

- Calculation of y -

$y = (My \cdot L_s / 3) / E_{eff} = 0.01489311$ ((4.29), Biskinis Phd))
 $My = 3.0318E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00
 From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 1.0179E+013$
 $factor = 0.30$
 $A_g = 125663.706$
 $f_c' = 33.00$
 $N = 4769.729$
 $E_c \cdot I_g = 3.3929E+013$

Calculation of Yielding Moment My

Calculation of y and My according to (7) - (8) in Biskinis and Fardis

$My = \min(My_{ten}, My_{com}) = 3.0318E+008$
 y ((10a) or (10b)) = 1.6222680E-005
 My_{ten} (8a) = 3.0318E+008
 y_{ten} (7a) = 69.35397
 error of function (7a) = 0.00743258
 My_{com} (8b) = 4.6746E+008
 y_{com} (7b) = 67.1564
 error of function (7b) = -0.00265541
 with $e_y = 0.0027778$
 $e_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00102226$
 $N = 4769.729$
 $A_c = 125663.706$
 $= 0.36359274$
 with f_c^* ((12.3), ACI 440) = 37.12975
 $f_c = 33.00$
 $f_l = 1.3173$
 $k = 1$
 Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 e_f ((12.5) and (12.7)) = 0.004
 $E_f = 64828.00$

Calculation of ratio l_b/d

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

- Calculation of p -

From table 10-9: $p = 0.005$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$
shear control ratio $V_{yE}/V_{ColOE} = 0.44725617$
 $d = 0.00$
 $s = 0.00$
 $t = 2 \cdot A_v / (d_c \cdot s) + 4 \cdot t_f / D \cdot (f_{fe} / f_s) = 0.00$
 $A_v = 78.53982$, is the area of the circular stirrup
 $d_c = D - 2 \cdot \text{cover} - \text{Hoop Diameter} = 340.00$
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.
 $NUD = 4769.729$
 $A_g = 125663.706$
 $f_{cE} = 33.00$
 $f_{ytE} = f_{ylE} = 555.56$
 $p_l = \text{Area_Tot_Long_Rein} / (A_g) = 0.0243$
 $f_{cE} = 33.00$

End Of Calculation of Chord Rotation Capacity for element: column CC1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 3

column C1, Floor 1

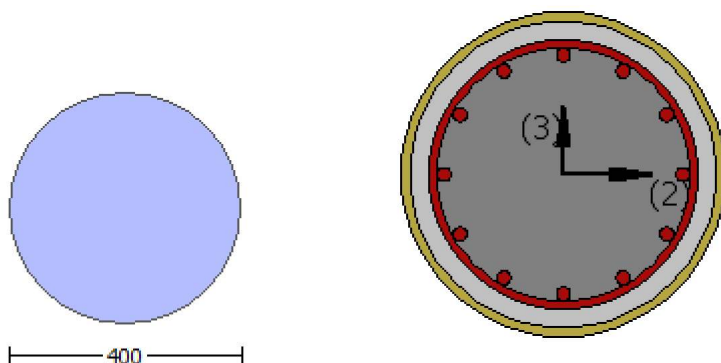
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column CC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rccs

Constant Properties

Knowledge Factor, $\gamma = 0.90$
 Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.
 Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$
 Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of γ for displacement ductility demand,
 the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as
 Deformation-Controlled Action (Table C7-1, ASCE41-17).
 New material: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material: Steel Strength, $f_s = f_{sm} = 555.56$
 #####
 Diameter, $D = 400.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{ou,min} = l_b/d \geq 1$)
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $\epsilon_{fu} = 0.01$
 Number of directions, $N_{oDir} = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $N_L = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = 6.3952987E-010$
 Shear Force, $V_a = -1.9910600E-013$
 EDGE -B-
 Bending Moment, $M_b = -4.1943110E-011$
 Shear Force, $V_b = 1.9910600E-013$
 BOTH EDGES
 Axial Force, $F = -4769.729$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{sl,t} = 1272.345$
 -Compression: $A_{sl,c} = 1781.283$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{sl,ten} = 1017.876$
 -Compression: $A_{sl,com} = 1017.876$
 -Middle: $A_{sl,mid} = 1017.876$
 Mean Diameter of Tension Reinforcement, $D_{bL,ten} = 18.00$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0 \cdot V_n = 393301.081$
 $V_n ((10.3), ASCE 41-17) = k_n l \cdot V_{CoI0} = 393301.081$
 $V_{CoI} = 393301.081$
 $k_n l = 1.00$
 $displacement_ductility_demand = 0.00$

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d/s$ ' is replaced by ' $V_{s+} = f \cdot V_f$ '

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

$= 1$ (normal-weight concrete)

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

$M/Vd = 2.00$

$\mu_u = 6.3952987E-010$

$V_u = 1.9910600E-013$

$d = 0.8 \cdot D = 320.00$

$N_u = 4769.729$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 197392.088$

$A_v = \frac{1}{2} A_{stirrup} = 123370.055$

$f_y = 500.00$

$s = 100.00$

V_s is multiplied by $\text{Col} = 0.00$

$s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 194961.134

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $tf1 = NL \cdot t / N_{Dir} = 1.016$

$dfv = d$ (figure 11.2, ACI 440) = 370.00

ffe ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 267132.42$

$bw \cdot d = \frac{1}{4} d^2 = 80424.772$

displacement ductility demand is calculated as δ / y

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

From analysis, chord rotation $\theta = 1.8835917E-020$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.01489311$ ((4.29), Biskinis Phd))

$M_y = 3.0318E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 1.0179E+013$

factor = 0.30

$A_g = 125663.706$

$f'_c = 33.00$

$N = 4769.729$

$E_c \cdot I_g = 3.3929E+013$

Calculation of Yielding Moment M_y

Calculation of δ and M_y according to (7) - (8) in Biskinis and Fardis

$M_y = \text{Min}(M_{y_ten}, M_{y_com}) = 3.0318E+008$

y ((10a) or (10b)) = 1.6222680E-005

M_{y_ten} (8a) = 3.0318E+008

δ_{ten} (7a) = 69.35397

error of function (7a) = 0.00743258

M_{y_com} (8b) = 4.6746E+008

δ_{com} (7b) = 67.1564

error of function (7b) = -0.00265541

with $e_y = 0.0027778$

$\epsilon_{co} = 0.002$
 $\alpha_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00102226$
 $N = 4769.729$
 $A_c = 125663.706$
 $= 0.36359274$
 with f_c^* ((12.3), ACI 440) = 37.12975
 $f_c = 33.00$
 $f_l = 1.3173$
 $k = 1$
 Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 ϵ_{fe} ((12.5) and (12.7)) = 0.004
 $E_f = 64828.00$

Calculation of ratio l_b/d

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

End Of Calculation of Shear Capacity for element: column CC1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 4

column C1, Floor 1

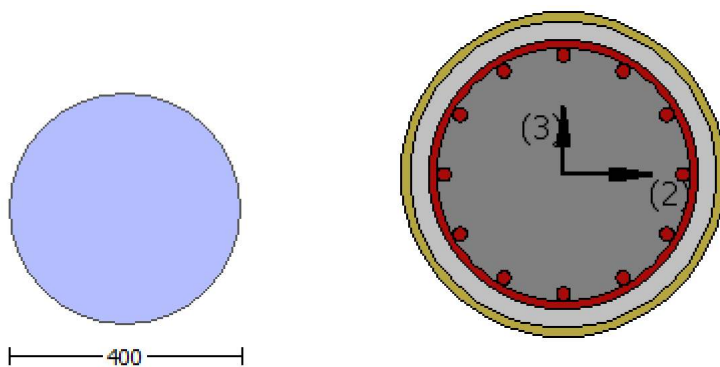
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ)

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rccs

Constant Properties

Knowledge Factor, $\phi = 0.90$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.56406

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 1.1167452E-031$

EDGE -B-

Shear Force, $V_b = -1.1167452E-031$

BOTH EDGES

Axial Force, $F = -4771.233$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{st,ten} = 1017.876$

-Compression: $A_{st,com} = 1017.876$

-Middle: $A_{st,mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.44725617$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 202038.041$

with

$M_{pr1} = \max(M_{u1+}, M_{u1-}) = 3.0306E+008$

$M_{u1+} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment

direction which is defined for the static loading combination

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 3.0306E+008$$

$M_{u2+} = 3.0306E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 3.0306E+008$, 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 Moment Strength ((3.67), Biskinis Phd), M_u
 $M_u = 3.0306E+008$

$$= 1.02974$$

$$\lambda = 0.91217079$$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TB DY: $f_{cc} = f_c \cdot \lambda = 51.61391$

$$\text{conf. factor } \lambda = 1.56406$$

$$f_c = 33.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00101663$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \lambda \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of M_{u1-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), M_u
 $M_u = 3.0306E+008$

$$= 1.02974$$

$$\lambda = 0.91217079$$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TB DY: $f_{cc} = f_c \cdot \lambda = 51.61391$

$$\text{conf. factor } \lambda = 1.56406$$

$$f_c = 33.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00101663$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \lambda \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of M_{u2+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02
From 5A.2, TBDY: fcc = fc* c = 51.61391
conf. factor c = 1.56406
fc = 33.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 694.45
lb/d = 1.00
d1 = 44.00
R = 200.00
v = 0.00101663
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.45184585

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02
From 5A.2, TBDY: fcc = fc* c = 51.61391
conf. factor c = 1.56406
fc = 33.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 694.45
lb/d = 1.00
d1 = 44.00
R = 200.00
v = 0.00101663
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.45184585

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 451727.786

Calculation of Shear Strength at edge 1, Vr1 = 451727.786

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

VColO = 451727.786

knl = 1 (zero step-static loading)

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

$\lambda = 1$ (normal-weight concrete)
 $f'_c = 33.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 1.5353150E-011$
 $\mu_v = 1.1167452E-031$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 219326.297$
 $A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 123370.055$
 $f_y = 555.56$
 $s = 100.00$
 V_s is multiplied by $\text{Col} = 0.00$
 $s/d = 0.3125$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 194961.134$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 370.00
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 306911.784$
 $b_w \cdot d = \sqrt{d} \cdot d / 4 = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 451727.786$
 $V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} \cdot V_{\text{Col}0}$
 $V_{\text{Col}0} = 451727.786$
 $k_{nl} = 1$ (zero step-static loading)

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

$\lambda = 1$ (normal-weight concrete)
 $f'_c = 33.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 1.5353150E-011$
 $\mu_v = 1.1167452E-031$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 219326.297$
 $A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 123370.055$
 $f_y = 555.56$
 $s = 100.00$
 V_s is multiplied by $\text{Col} = 0.00$
 $s/d = 0.3125$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 194961.134$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

```

ffe ((11-5), ACI 440) = 259.312
Ef = 64828.00
fe = 0.004, from (11.6a), ACI 440
with fu = 0.01
From (11-11), ACI 440: Vs + Vf <= 306911.784
bw*d = *d*d/4 = 80424.772
-----

End Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1
At local axis: 3
-----

Start Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rccs

Constant Properties
-----
Knowledge Factor, k = 0.90
Mean strength values are used for both shear and moment calculations.
Consequently:
New material of Secondary Member: Concrete Strength, fc = fcm = 33.00
New material of Secondary Member: Steel Strength, fs = fsm = 555.56
Concrete Elasticity, Ec = 26999.444
Steel Elasticity, Es = 200000.00
#####
Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
New material: Steel Strength, fs = 1.25*fsm = 694.45
#####
Diameter, D = 400.00
Cover Thickness, c = 25.00
Mean Confinement Factor overall section = 1.56406
Element Length, L = 3000.00
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length (lo/lou, min >= 1)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, ffu = 1055.00
Tensile Modulus, Ef = 64828.00
Elongation, efu = 0.01
Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00
-----

Stepwise Properties
-----
At local axis: 2
EDGE -A-
Shear Force, Va = -6.8378665E-048
EDGE -B-
Shear Force, Vb = 6.8378665E-048
BOTH EDGES
Axial Force, F = -4771.233
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00

```

-Compression: $Asl_c = 3053.628$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $Asl_{ten} = 1017.876$
-Compression: $Asl_{com} = 1017.876$
-Middle: $Asl_{mid} = 1017.876$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.44725617$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 202038.041$
with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 3.0306E+008$
 $\mu_{u1+} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $\mu_{u1-} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 3.0306E+008$
 $\mu_{u2+} = 3.0306E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the the static loading combination
 $\mu_{u2-} = 3.0306E+008$, 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 Moment Strength ((3.67), Biskinis Phd), μ_u
 $\mu_u = 3.0306E+008$

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02
From 5A.2, TBDY: $f_{cc} = f_c^* \quad c = 51.61391$
conf. factor $c = 1.56406$
 $f_c = 33.00$
From 10.3.5, ASCE41-17, Final value of f_y : $f_y * \text{Min}(1, 1.25 * (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$
 $A_c = 125663.706$
= $*\text{Min}(1, 1.25 * (l_b/d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/d

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

Calculation of μ_{u1-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ_u
 $\mu_u = 3.0306E+008$

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02
From 5A.2, TBDY: $f_{cc} = f_c^* \quad c = 51.61391$
conf. factor $c = 1.56406$
 $f_c = 33.00$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00101663$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of μ_{2+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ

$$\mu = 3.0306 \times 10^8$$

$$= 1.02974$$

$$' = 0.91217079$$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 51.61391$

$$\text{conf. factor } c = 1.56406$$

$$f_c = 33.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00101663$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of μ_{2-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ

$$\mu = 3.0306 \times 10^8$$

$$= 1.02974$$

$$' = 0.91217079$$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 51.61391$

$$\text{conf. factor } c = 1.56406$$

$$f_c = 33.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00101663$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 451727.786$

Calculation of Shear Strength at edge 1, $V_{r1} = 451727.786$

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

$V_{\text{ColO}} = 451727.786$

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

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

$= 1$ (normal-weight concrete)

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

$M/Vd = 2.00$

$\mu_u = 5.4715235\text{E-}012$

$\nu_u = 6.8378665\text{E-}048$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 219326.297$

$A_v = \frac{1}{2} \cdot A_{\text{stirrup}} = 123370.055$

$f_y = 555.56$

$s = 100.00$

V_s is multiplied by $\text{Col} = 0.00$

$s/d = 0.3125$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 194961.134$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 306911.784$

$b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 451727.786$

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

$V_{\text{ColO}} = 451727.786$

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

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

$= 1$ (normal-weight concrete)

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

$M/Vd = 2.00$

$\mu_u = 5.4715235\text{E-}012$

$\nu_u = 6.8378665\text{E-}048$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 219326.297$

$A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 123370.055$

$f_y = 555.56$

$s = 100.00$

V_s is multiplied by $\text{Col} = 0.00$

$s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 194961.134

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 306911.784$

$b_w \cdot d = \pi \cdot d^2 / 4 = 80424.772$

End Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column CC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rccs

Constant Properties

Knowledge Factor, $\phi = 0.90$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $\text{NoDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -1.1282\text{E}+007$

Shear Force, $V2 = -3759.209$

Shear Force, $V3 = -1.9910600\text{E}-013$

Axial Force, $F = -4769.729$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 1272.345$

-Compression: $As_c = 1781.283$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1017.876$

-Compression: $As_{l,com} = 1017.876$

-Middle: $As_{l,mid} = 1017.876$

Mean Diameter of Tension Reinforcement, $Db_L = 18.00$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = 1.0^*$ $u = 0.03479765$

$u = y + p = 0.03479765$

- Calculation of y -

$y = (My * L_s / 3) / E_{eff} = 0.02979765$ ((4.29), Biskinis Phd))

$My = 3.0318\text{E}+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3001.151

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 1.0179\text{E}+013$

factor = 0.30

$A_g = 125663.706$

$f_c' = 33.00$

$N = 4769.729$

$E_c * I_g = 3.3929\text{E}+013$

Calculation of Yielding Moment My

Calculation of y and My according to (7) - (8) in Biskinis and Fardis

$My = \text{Min}(My_{ten}, My_{com}) = 3.0318\text{E}+008$

y ((10a) or (10b)) = 1.6222680E-005

My_{ten} (8a) = 3.0318E+008

y_{ten} (7a) = 69.35397

error of function (7a) = 0.00743258

My_{com} (8b) = 4.6746E+008

y_{com} (7b) = 67.1564

error of function (7b) = -0.00265541

with $e_y = 0.0027778$

$e_{co} = 0.002$

$a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)

$d_1 = 44.00$

$R = 200.00$

$v = 0.00102226$

$N = 4769.729$

$A_c = 125663.706$

= 0.36359274

with f_c^* ((12.3), ACI 440) = 37.12975

$f_c = 33.00$

$f_l = 1.3173$

$k = 1$

Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$

e_{fe} ((12.5) and (12.7)) = 0.004

$E_f = 64828.00$

Calculation of ratio l_b/l_d

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

- Calculation of ρ -

From table 10-9: $\rho = 0.005$

with:

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

shear control ratio $V_y E / V_{Col} E = 0.44725617$

$d = 0.00$

$s = 0.00$

$t = 2 \cdot A_v / (d_c \cdot s) + 4 \cdot t_f / D \cdot (f_{fe} / f_s) = 0.00$

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

$d_c = D - 2 \cdot \text{cover} - \text{Hoop Diameter} = 340.00$

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.

$N_{UD} = 4769.729$

$A_g = 125663.706$

$f_{cE} = 33.00$

$f_{ytE} = f_{yIE} = 555.56$

$\rho_l = \text{Area_Tot_Long_Rein} / (A_g) = 0.0243$

$f_{cE} = 33.00$

End Of Calculation of Chord Rotation Capacity for element: column CC1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 5

column C1, Floor 1

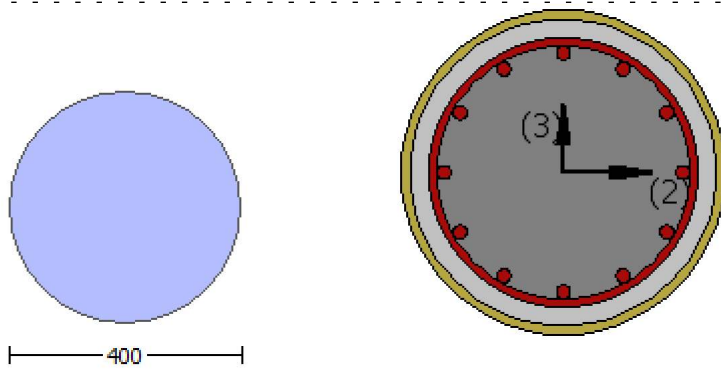
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column CC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rccs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

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

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

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

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -1.1282E+007$

Shear Force, $V_a = -3759.209$

EDGE -B-

Bending Moment, $M_b = 0.06021356$

Shear Force, $V_b = 3759.209$

BOTH EDGES

Axial Force, $F = -4769.729$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1017.876$

-Compression: $As_{c,com} = 1017.876$

-Middle: $As_{mid} = 1017.876$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.00$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0 \cdot V_n = 393301.081$

V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{Col} = 393301.081$

$V_{Col} = 393301.081$

$k_n = 1.00$

$displacement_ductility_demand = 0.05581234$

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

= 1 (normal-weight concrete)

$f'_c = 25.00$, but $f'_c \cdot 0.5 \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/V_d = 2.00$

$\mu_u = 0.06021356$

$V_u = 3759.209$

$d = 0.8 \cdot D = 320.00$

$N_u = 4769.729$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 197392.088$

$A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$

$f_y = 500.00$

$s = 100.00$

V_s is multiplied by $Col = 0.00$

$s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 194961.134

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \alpha + \cos \alpha$ is replaced with $(\cot \alpha + \cot \alpha) \sin \alpha$ which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\alpha_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|)$, with:

total thickness per orientation, $tf_1 = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 267132.42$

$b_w \cdot d = \sqrt{2} \cdot d^2 / 4 = 80424.772$

$displacement_ductility_demand$ is calculated as Δ / y

- Calculation of Δ / y for END B -

for rotation axis 3 and integ. section (b)

From analysis, chord rotation $\theta = 0.00016624$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00297862$ ((4.29), Biskinis Phd))

$M_y = 3.0318E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00

From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 1.0179E+013$

factor = 0.30
Ag = 125663.706
fc' = 33.00
N = 4769.729
Ec*Ig = 3.3929E+013

Calculation of Yielding Moment My

Calculation of ϕ_y and My according to (7) - (8) in Biskinis and Fardis

My = Min(My_ten, My_com) = 3.0318E+008
 ϕ_y ((10a) or (10b)) = 1.6222680E-005
My_ten (8a) = 3.0318E+008
 ϕ_{ten} (7a) = 69.35397
error of function (7a) = 0.00743258
My_com (8b) = 4.6746E+008
 ϕ_{com} (7b) = 67.1564
error of function (7b) = -0.00265541
with ϕ_y = 0.0027778
 ϕ_{co} = 0.002
 ϕ_{pl} = 0.45 ((9c) in Biskinis and Fardis for FRP Wrap)
d1 = 44.00
R = 200.00
 ν = 0.00102226
N = 4769.729
Ac = 125663.706
 ϕ_{co} = 0.36359274
with ϕ_{co}^* ((12.3), ACI 440) = 37.12975
fc = 33.00
 ϕ_l = 1.3173
k = 1
Effective FRP thickness, t_f = NL*t*cos(b1) = 1.016
 ϕ_{fe} ((12.5) and (12.7)) = 0.004
Ef = 64828.00

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

End Of Calculation of Shear Capacity for element: column CC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 6

column C1, Floor 1

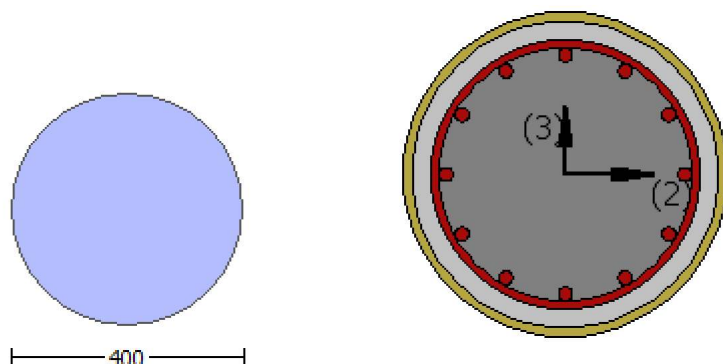
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ)

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rccs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.56406

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 1.1167452E-031$

EDGE -B-

Shear Force, $V_b = -1.1167452E-031$

BOTH EDGES

Axial Force, $F = -4771.233$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1017.876$

-Compression: $As_{l,com} = 1017.876$

-Middle: $As_{l,mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.44725617$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 202038.041$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 3.0306E+008$

$Mu_{1+} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 3.0306E+008$

$Mu_{2+} = 3.0306E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 3.0306E+008$, 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 Moment Strength ((3.67), Biskinis Phd), M_u

$M_u = 3.0306E+008$

$\phi = 1.02974$

$\phi' = 0.91217079$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TBDY: $f_{cc} = f_c' \cdot c = 51.61391$

conf. factor $c = 1.56406$

$f_c = 33.00$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 694.45$

$l_b/l_d = 1.00$

$d_1 = 44.00$

$R = 200.00$

$v = 0.00101663$

$N = 4771.233$

$A_c = 125663.706$

$= \phi' \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/l_d

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

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02
From 5A.2, TBDY: fcc = fc* c = 51.61391
conf. factor c = 1.56406
fc = 33.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 694.45
lb/d = 1.00
d1 = 44.00
R = 200.00
v = 0.00101663
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.45184585

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02
From 5A.2, TBDY: fcc = fc* c = 51.61391
conf. factor c = 1.56406
fc = 33.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 694.45
lb/d = 1.00
d1 = 44.00
R = 200.00
v = 0.00101663
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.45184585

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974

$\lambda = 0.91217079$
 error of function (3.68), Biskinis Phd = 60360.02
 From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 51.61391$
 conf. factor $c = 1.56406$
 $f_c = 33.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 451727.786$

Calculation of Shear Strength at edge 1, $V_{r1} = 451727.786$

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

$V_{Col0} = 451727.786$

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

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

$= 1$ (normal-weight concrete)

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

$M/Vd = 2.00$

$\mu_u = 1.5353150E-011$

$\nu_u = 1.1167452E-031$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 219326.297$

$A_v = \frac{1}{2} \cdot A_{\text{stirrup}} = 123370.055$

$f_y = 555.56$

$s = 100.00$

V_s is multiplied by $\text{Col} = 0.00$

$s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 194961.134

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,

where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 306911.784$

$b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 451727.786$

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

VColO = 451727.786

kn1 = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)

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

$M/Vd = 2.00$

$\mu_u = 1.5353150E-011$

$\mu_u = 1.1167452E-031$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 219326.297$

$A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$

$f_y = 555.56$

$s = 100.00$

V_s is multiplied by $\text{Col} = 0.00$

$s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 194961.134

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 306911.784$

$b_w \cdot d = \sqrt{2} \cdot d \cdot d / 4 = 80424.772$

End Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rccs

Constant Properties

Knowledge Factor, $\phi = 0.90$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.56406

Element Length, L = 3000.00
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{ou}, \min \geq 1$)
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, t = 1.016
 Tensile Strength, f_{fu} = 1055.00
 Tensile Modulus, E_f = 64828.00
 Elongation, ϵ_{fu} = 0.01
 Number of directions, NoDir = 1
 Fiber orientations, b_i : 0.00°
 Number of layers, NL = 1
 Radius of rounding corners, R = 40.00

Stepwise Properties

At local axis: 2
 EDGE -A-
 Shear Force, V_a = -6.8378665E-048
 EDGE -B-
 Shear Force, V_b = 6.8378665E-048
 BOTH EDGES
 Axial Force, F = -4771.233
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: A_{st} = 0.00
 -Compression: A_{sc} = 3053.628
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{st,ten}$ = 1017.876
 -Compression: $A_{st,com}$ = 1017.876
 -Middle: $A_{st,mid}$ = 1017.876

Calculation of Shear Capacity ratio, V_e/V_r = 0.44725617
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 202038.041$
 with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 3.0306E+008$
 $\mu_{u1+} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u1-} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 3.0306E+008$
 $\mu_{u2+} = 3.0306E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u2-} = 3.0306E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of μ_{u1+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ_u
 $\mu_u = 3.0306E+008$

= 1.02974
 ' = 0.91217079
 error of function (3.68), Biskinis Phd = 60360.02
 From 5A.2, TBDY: $f_{cc} = f_c^* \quad c = 51.61391$

conf. factor $c = 1.56406$
 $f_c = 33.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$
 $Ac = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/d

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

Calculation of μ_1 -

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 3.0306E+008$

$= 1.02974$
 $' = 0.91217079$
 error of function (3.68), Biskinis Phd = 60360.02
 From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 51.61391$
 conf. factor $c = 1.56406$
 $f_c = 33.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$
 $Ac = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/d

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

Calculation of μ_2 +

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 3.0306E+008$

$= 1.02974$
 $' = 0.91217079$
 error of function (3.68), Biskinis Phd = 60360.02
 From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 51.61391$
 conf. factor $c = 1.56406$
 $f_c = 33.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$
 $Ac = 125663.706$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of μ_2

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 3.0306 \times 10^8$

$$= 1.02974$$

$$\lambda = 0.91217079$$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 51.61391$

conf. factor $c = 1.56406$

$f_c = 33.00$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00101663$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 451727.786$

Calculation of Shear Strength at edge 1, $V_{r1} = 451727.786$

$V_{r1} = V_{co1} \text{ ((10.3), ASCE 41-17)} = k_{nl} \cdot V_{co10}$

$$V_{co10} = 451727.786$$

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

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

$= 1$ (normal-weight concrete)

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

$$M/Vd = 2.00$$

$$\mu_u = 5.4715235 \times 10^{-12}$$

$$V_u = 6.8378665 \times 10^{-48}$$

$$d = 0.8 \cdot D = 320.00$$

$$N_u = 4771.233$$

$$A_g = 125663.706$$

From (11.5.4.8), ACI 318-14: $V_s = 219326.297$

$$A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 123370.055$$

$$f_y = 555.56$$

$$s = 100.00$$

V_s is multiplied by $\text{Col} = 0.00$

$$s/d = 0.3125$$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 194961.134$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot_a) \sin a$ which is more a generalised expression,

where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

$f_{fe}((11-5), \text{ACI 440}) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 306911.784$

$b_w \cdot d = \rho \cdot d^2 / 4 = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 451727.786$

$V_{r2} = V_{\text{Col}}((10.3), \text{ASCE 41-17}) = k_{nl} \cdot V_{\text{Col}0}$

$V_{\text{Col}0} = 451727.786$

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

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

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

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

$M/Vd = 2.00$

$\mu_u = 5.4715235E-012$

$\nu_u = 6.8378665E-048$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 219326.297$

$A_v = \rho / 2 \cdot A_{\text{stirrup}} = 123370.055$

$f_y = 555.56$

$s = 100.00$

V_s is multiplied by $\rho_{\text{Col}} = 0.00$

$s/d = 0.3125$

$V_f((11-3)-(11.4), \text{ACI 440}) = 194961.134$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

$f_{fe}((11-5), \text{ACI 440}) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 306911.784$

$b_w \cdot d = \rho \cdot d^2 / 4 = 80424.772$

End Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column CC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rccs

Constant Properties

Knowledge Factor, $\phi = 0.90$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/l_d \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -4.1943110E-011$

Shear Force, $V_2 = 3759.209$

Shear Force, $V_3 = 1.9910600E-013$

Axial Force, $F = -4769.729$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{st,ten} = 1017.876$

-Compression: $A_{st,com} = 1017.876$

-Middle: $A_{st,mid} = 1017.876$

Mean Diameter of Tension Reinforcement, $D_bL = 18.00$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = 1.0^* u = 0.01989311$

$u = y + p = 0.01989311$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.01489311$ ((4.29), Biskinis Phd))

$M_y = 3.0318E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 1.0179E+013$

factor = 0.30

$A_g = 125663.706$

$f_c' = 33.00$

$N = 4769.729$

$E_c * I_g = 3.3929E+013$

Calculation of Yielding Moment M_y

Calculation of ρ_y and M_y according to (7) - (8) in Biskinis and Fardis

$M_y = \text{Min}(M_{y_ten}, M_{y_com}) = 3.0318\text{E}+008$
 $\rho_y \text{ ((10a) or (10b))} = 1.6222680\text{E}-005$
 $M_{y_ten} \text{ (8a)} = 3.0318\text{E}+008$
 $\rho_{y_ten} \text{ (7a)} = 69.35397$
error of function (7a) = 0.00743258
 $M_{y_com} \text{ (8b)} = 4.6746\text{E}+008$
 $\rho_{y_com} \text{ (7b)} = 67.1564$
error of function (7b) = -0.00265541
with $e_y = 0.0027778$
 $e_{co} = 0.002$
 $a_{pl} = 0.45 \text{ ((9c) in Biskinis and Fardis for FRP Wrap)}$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00102226$
 $N = 4769.729$
 $A_c = 125663.706$
 $= 0.36359274$
with $f_c^* \text{ ((12.3), ACI 440)} = 37.12975$
 $f_c = 33.00$
 $f_l = 1.3173$
 $k = 1$
Effective FRP thickness, $t_f = N L^* t \cos(\beta_1) = 1.016$
 $e_{fe} \text{ ((12.5) and (12.7))} = 0.004$
 $E_f = 64828.00$

Calculation of ratio l_b/l_d

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

- Calculation of ρ_p -

From table 10-9: $\rho_p = 0.005$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$
shear control ratio $V_y E / V_{co} I_{OE} = 0.44725617$
 $d = 0.00$
 $s = 0.00$
 $t = 2 A_v / (d_c s) + 4 t_f / D (f_{fe} / f_s) = 0.00$
 $A_v = 78.53982$, is the area of the circular stirrup
 $d_c = D - 2 \text{ cover} - \text{Hoop Diameter} = 340.00$
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.
 $N_{UD} = 4769.729$
 $A_g = 125663.706$
 $f_{cE} = 33.00$
 $f_{yE} = f_{yI} = 555.56$
 $\rho_l = \text{Area_Tot_Long_Rein} / (A_g) = 0.0243$
 $f_{cE} = 33.00$

End Of Calculation of Chord Rotation Capacity for element: column CC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 7

column C1, Floor 1

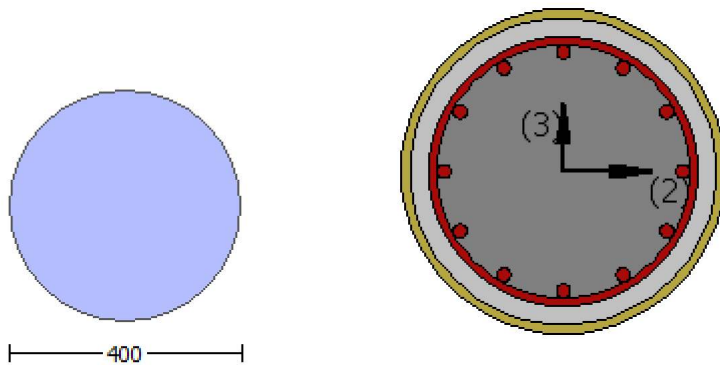
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column CC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rccs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

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

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

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

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $\epsilon_{fu} = 0.01$
 Number of directions, $NoDir = 1$
 Fiber orientations, $b_i = 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = 6.3952987E-010$
 Shear Force, $V_a = -1.9910600E-013$
 EDGE -B-
 Bending Moment, $M_b = -4.1943110E-011$
 Shear Force, $V_b = 1.9910600E-013$
 BOTH EDGES
 Axial Force, $F = -4769.729$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_{lt} = 0.00$
 -Compression: $As_{lc} = 3053.628$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{l,ten} = 1017.876$
 -Compression: $As_{l,com} = 1017.876$
 -Middle: $As_{l,mid} = 1017.876$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.00$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0 \cdot V_n = 393301.081$
 $V_n ((10.3), ASCE 41-17) = knl \cdot V_{Col} = 393301.081$
 $V_{Col} = 393301.081$
 $knl = 1.00$
 $displacement_ductility_demand = 0.00$

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

$= 1$ (normal-weight concrete)
 $f'_c = 25.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 4.1943110E-011$
 $V_u = 1.9910600E-013$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4769.729$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 197392.088$
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 500.00$
 $s = 100.00$
 V_s is multiplied by $Col = 0.00$
 $s/d = 0.3125$
 $V_f ((11-3)-(11.4), ACI 440) = 194961.134$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(,)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $a_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $tf_1 = NL \cdot t / NoDir = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 267132.42$
 $b_w \cdot d = \frac{d^2}{4} = 80424.772$

displacement ductility demand is calculated as $\frac{\Delta}{y}$

- Calculation of $\frac{\Delta}{y}$ for END B -
for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 9.9377781E-021$
 $y = \frac{M_y \cdot L_s}{3} / E_{eff} = 0.01489311$ ((4.29), Biskinis Phd))
 $M_y = 3.0318E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 1.0179E+013$
 $\text{factor} = 0.30$
 $A_g = 125663.706$
 $f'_c = 33.00$
 $N = 4769.729$
 $E_c \cdot I_g = 3.3929E+013$

Calculation of Yielding Moment M_y

Calculation of $\frac{\Delta}{y}$ and M_y according to (7) - (8) in Biskinis and Fardis

$M_y = \min(M_{y_ten}, M_{y_com}) = 3.0318E+008$
 y ((10a) or (10b)) = 1.6222680E-005
 M_{y_ten} (8a) = 3.0318E+008
 $\frac{\Delta}{y}$ (7a) = 69.35397
 error of function (7a) = 0.00743258
 M_{y_com} (8b) = 4.6746E+008
 $\frac{\Delta}{y}$ (7b) = 67.1564
 error of function (7b) = -0.00265541
 with $e_y = 0.0027778$
 $e_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00102226$
 $N = 4769.729$
 $A_c = 125663.706$
 $\rho = 0.36359274$
 with f'_c ((12.3), ACI 440) = 37.12975
 $f_c = 33.00$
 $f_l = 1.3173$
 $k = 1$
 Effective FRP thickness, $t_f = N \cdot t \cdot \cos(b_1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $E_f = 64828.00$

Calculation of ratio l_b/d

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

End Of Calculation of Shear Capacity for element: column CC1 of floor 1
 At local axis: 3
 Integration Section: (b)

Calculation No. 8

column C1, Floor 1

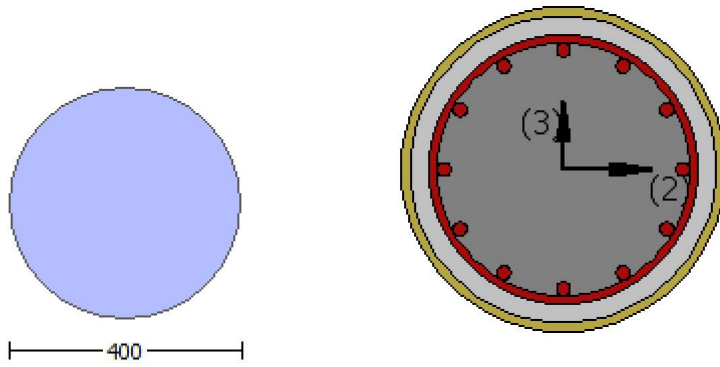
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ_r)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rccs

Constant Properties

Knowledge Factor, $\phi = 0.90$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.56406

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 1.1167452E-031$

EDGE -B-

Shear Force, $V_b = -1.1167452E-031$

BOTH EDGES

Axial Force, $F = -4771.233$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1017.876$

-Compression: $A_{sl,com} = 1017.876$

-Middle: $A_{sl,mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.44725617$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 202038.041$ with

$M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 3.0306E+008$

$\mu_{u1+} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{u1-} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 3.0306E+008$

$\mu_{u2+} = 3.0306E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{u2-} = 3.0306E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of μ_{u1+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ_u

$\mu_u = 3.0306E+008$

$\beta = 1.02974$

$\beta' = 0.91217079$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TBDY: $f_{cc} = f_c' \cdot c = 51.61391$

conf. factor $c = 1.56406$

$f_c = 33.00$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \min(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 694.45$

$l_b/l_d = 1.00$

$d_1 = 44.00$

$R = 200.00$

$v = 0.00101663$

$$N = 4771.233$$

$$Ac = 125663.706$$

$$= *Min(1, 1.25*(lb/d)^{2/3}) = 0.45184585$$

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

$$= 1.02974$$

$$' = 0.91217079$$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TBDY: fcc = fc* c = 51.61391

conf. factor c = 1.56406

fc = 33.00

From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1, 1.25*(lb/d)^{2/3}) = 694.45

lb/d = 1.00

d1 = 44.00

R = 200.00

v = 0.00101663

N = 4771.233

Ac = 125663.706

$$= *Min(1, 1.25*(lb/d)^{2/3}) = 0.45184585$$

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

$$= 1.02974$$

$$' = 0.91217079$$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TBDY: fcc = fc* c = 51.61391

conf. factor c = 1.56406

fc = 33.00

From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1, 1.25*(lb/d)^{2/3}) = 694.45

lb/d = 1.00

d1 = 44.00

R = 200.00

v = 0.00101663

N = 4771.233

Ac = 125663.706

$$= *Min(1, 1.25*(lb/d)^{2/3}) = 0.45184585$$

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02
From 5A.2, TBDY: $f_{cc} = f_c' \cdot c = 51.61391$
conf. factor $c = 1.56406$
 $f_c = 33.00$
From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$
 $A_c = 125663.706$
= $\cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$

Calculation of ratio lb/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 451727.786$

Calculation of Shear Strength at edge 1, $V_{r1} = 451727.786$
 $V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l \cdot V_{Col0}$
 $V_{Col0} = 451727.786$
 $k_n l = 1$ (zero step-static loading)

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

= 1 (normal-weight concrete)
 $f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 1.5353150E-011$
 $V_u = 1.1167452E-031$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
From (11.5.4.8), ACI 318-14: $V_s = 219326.297$
 $A_v = \frac{1}{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 555.56$
 $s = 100.00$
 V_s is multiplied by $Col = 0.00$
 $s/d = 0.3125$
 V_f ((11-3)-(11.4), ACI 440) = 194961.134
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
where a is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:
total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

$f_{fe} ((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 306911.784$
 $b_w \cdot d = \frac{A_s \cdot d}{4} = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 451727.786$
 $V_{r2} = V_{Col} ((10.3), \text{ASCE } 41-17) = k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 451727.786$
 $k_{nl} = 1$ (zero step-static loading)

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

$= 1$ (normal-weight concrete)
 $f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 1.5353150E-011$
 $V_u = 1.1167452E-031$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 219326.297$
 $A_v = \frac{A_{stirrup}}{2} = 123370.055$
 $f_y = 555.56$
 $s = 100.00$
 V_s is multiplied by $Col = 0.00$
 $s/d = 0.3125$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 194961.134$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 370.00
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 306911.784$
 $b_w \cdot d = \frac{A_s \cdot d}{4} = 80424.772$

End Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1
 At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rccs

Constant Properties

Knowledge Factor, $\phi = 0.90$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$
 #####
 Diameter, $D = 400.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.56406
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{ou}, \min \geq 1$)
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $NoDir = 1$
 Fiber orientations, $bi: 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
 EDGE -A-
 Shear Force, $V_a = -6.8378665E-048$
 EDGE -B-
 Shear Force, $V_b = 6.8378665E-048$
 BOTH EDGES
 Axial Force, $F = -4771.233$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 0.00$
 -Compression: $As_c = 3053.628$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{t,ten} = 1017.876$
 -Compression: $As_{l,com} = 1017.876$
 -Middle: $As_{l,mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.44725617$
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 202038.041$
 with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 3.0306E+008$
 $\mu_{u1+} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
 which is defined for the static loading combination
 $\mu_{u1-} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
 direction which is defined for the static loading combination
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 3.0306E+008$
 $\mu_{u2+} = 3.0306E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
 which is defined for the the static loading combination
 $\mu_{u2-} = 3.0306E+008$, 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 Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02
From 5A.2, TBDY: fcc = fc* c = 51.61391
conf. factor c = 1.56406
fc = 33.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 694.45
lb/d = 1.00
d1 = 44.00
R = 200.00
v = 0.00101663
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.45184585

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02
From 5A.2, TBDY: fcc = fc* c = 51.61391
conf. factor c = 1.56406
fc = 33.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 694.45
lb/d = 1.00
d1 = 44.00
R = 200.00
v = 0.00101663
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.45184585

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TBDY: $f_{cc} = f_c' \cdot c = 51.61391$
 conf. factor $c = 1.56406$
 $f_c = 33.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/d

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

Calculation of μ_2 -

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 3.0306E+008$

$= 1.02974$
 $' = 0.91217079$
 error of function (3.68), Biskinis Phd = 60360.02
 From 5A.2, TBDY: $f_{cc} = f_c' \cdot c = 51.61391$
 conf. factor $c = 1.56406$
 $f_c = 33.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 451727.786$

Calculation of Shear Strength at edge 1, $V_{r1} = 451727.786$
 $V_{r1} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = k_{nl} \cdot V_{CoI0}$
 $V_{CoI0} = 451727.786$
 $k_{nl} = 1$ (zero step-static loading)

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

$= 1$ (normal-weight concrete)
 $f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu = 5.4715235E-012$
 $V_u = 6.8378665E-048$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 219326.297$

$A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 123370.055$

$f_y = 555.56$

$s = 100.00$

V_s is multiplied by $\text{Col} = 0.00$

$s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 194961.134

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation θ_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 306911.784$

$b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 451727.786$

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

$V_{\text{ColO}} = 451727.786$

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

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

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

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

$M/Vd = 2.00$

$\mu_u = 5.4715235\text{E-}012$

$\nu_u = 6.8378665\text{E-}048$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 219326.297$

$A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 123370.055$

$f_y = 555.56$

$s = 100.00$

V_s is multiplied by $\text{Col} = 0.00$

$s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 194961.134

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation θ_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 306911.784$

$b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 80424.772$

End Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column CC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rccs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/l_d \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 0.06021356$

Shear Force, $V_2 = 3759.209$

Shear Force, $V_3 = 1.9910600E-013$

Axial Force, $F = -4769.729$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1017.876$

-Compression: $A_{sl,com} = 1017.876$

-Middle: $A_{sl,mid} = 1017.876$

Mean Diameter of Tension Reinforcement, $D_{bL} = 18.00$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = 1.0^* u = 0.00797862$

$u = \gamma + p = 0.00797862$

- Calculation of γ -

$\gamma = (M_y * L_s / 3) / E_{eff} = 0.00297862 ((4.29), \text{Biskinis Phd})$

$M_y = 3.0318E+008$
 $L_s = M/V$ (with $L_s > 0.1*L$ and $L_s < 2*L$) = 300.00
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.0179E+013$
 $factor = 0.30$
 $A_g = 125663.706$
 $f_c' = 33.00$
 $N = 4769.729$
 $E_c * I_g = 3.3929E+013$

Calculation of Yielding Moment M_y

Calculation of ϕ_y and M_y according to (7) - (8) in Biskinis and Fardis

$M_y = \min(M_{y_ten}, M_{y_com}) = 3.0318E+008$
 ϕ_y ((10a) or (10b)) = 1.6222680E-005
 M_{y_ten} (8a) = 3.0318E+008
 ϕ_{y_ten} (7a) = 69.35397
 error of function (7a) = 0.00743258
 M_{y_com} (8b) = 4.6746E+008
 ϕ_{y_com} (7b) = 67.1564
 error of function (7b) = -0.00265541
 with $e_y = 0.0027778$
 $e_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00102226$
 $N = 4769.729$
 $A_c = 125663.706$
 $\phi = 0.36359274$
 with $f_c' = 33.00$ ((12.3), ACI 440) = 37.12975
 $f_c = 33.00$
 $f_l = 1.3173$
 $k = 1$
 Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $E_f = 64828.00$

Calculation of ratio I_b/I_d

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

- Calculation of ϕ_p -

From table 10-9: $\phi_p = 0.005$

with:

- Columns controlled by inadequate development or splicing along the clear height because $I_b/I_d < 1$
 $shear\ control\ ratio\ V_{yE}/V_{ColOE} = 0.44725617$
 $d = 0.00$
 $s = 0.00$
 $t = 2 * A_v / (d_c * s) + 4 * t_f / D * (f_{fe} / f_s) = 0.00$
 $A_v = 78.53982$, is the area of the circular stirrup
 $d_c = D - 2 * cover - Hoop\ Diameter = 340.00$
 The term $2 * t_f / bw * (f_{fe} / f_s)$ is implemented to account for FRP contribution
 where $f = 2 * t_f / bw$ 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.
 $NUD = 4769.729$
 $A_g = 125663.706$
 $f_cE = 33.00$
 $f_{ytE} = f_{ylE} = 555.56$
 $\phi_l = Area_Tot_Long_Rein / (A_g) = 0.0243$
 $f_cE = 33.00$

End Of Calculation of Chord Rotation Capacity for element: column CC1 of floor 1

At local axis: 3

Integration Section: (b)

Calculation No. 9

column C1, Floor 1

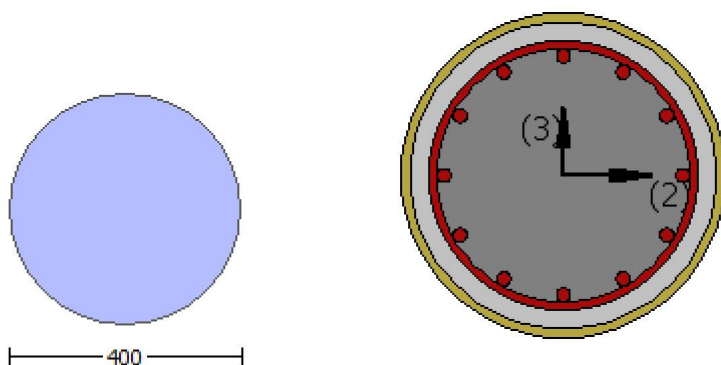
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VR_d

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column CC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rccs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

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

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

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

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, L = 3000.00
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{ou,min} = l_b/l_d \geq 1$)
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, t = 1.016
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $\epsilon_{fu} = 0.01$
 Number of directions, NoDir = 1
 Fiber orientations, $b_i = 0.00^\circ$
 Number of layers, NL = 1
 Radius of rounding corners, R = 40.00

Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = -9.0263E+006$
 Shear Force, $V_a = -3007.62$
 EDGE -B-
 Bending Moment, $M_b = 0.0481749$
 Shear Force, $V_b = 3007.62$
 BOTH EDGES
 Axial Force, $F = -4770.03$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{sl,t} = 1272.345$
 -Compression: $A_{sl,c} = 1781.283$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{sl,ten} = 1017.876$
 -Compression: $A_{sl,com} = 1017.876$
 -Middle: $A_{sl,mid} = 1017.876$
 Mean Diameter of Tension Reinforcement, $D_{bL,ten} = 18.00$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0 \cdot V_n = 330216.78$
 $V_n ((10.3), ASCE 41-17) = k_n \cdot V_{CoI0} = 330216.78$
 $V_{CoI} = 330216.78$
 $k_n = 1.00$
 displacement_ductility_demand = 0.00814822

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

= 1 (normal-weight concrete)
 $f'_c = 25.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 9.0263E+006$
 $V_u = 3007.62$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4770.03$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 197392.088$
 $A_v = /2 \cdot A_{stirrup} = 123370.055$
 $f_y = 500.00$
 $s = 100.00$
 V_s is multiplied by $CoI = 0.00$
 $s/d = 0.3125$
 $V_f ((11-3)-(11.4), ACI 440) = 194961.134$
 $f = 0.95$, for fully-wrapped sections

$wf/sf = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $Vf(\alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\alpha_1 = 45^\circ$ and $\alpha_2 = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\alpha_1 = b1 + 90^\circ = 90.00$

$Vf = \text{Min}(|Vf(45, \alpha_1)|, |Vf(-45, \alpha_1)|)$, with:

total thickness per orientation, $tf1 = NL \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + Vf \leq 267132.42$

$bw \cdot d = \sigma \cdot d \cdot d / 4 = 80424.772$

displacement_ductility_demand is calculated as δ / y

- Calculation of δ / y for END A -

for rotation axis 3 and integ. section (a)

From analysis, chord rotation $\theta = 0.0002428$

$y = (My \cdot L_s / 3) / E_{eff} = 0.02979765$ ((4.29), Biskinis Phd))

$My = 3.0318E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 3001.151

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 1.0179E+013$

factor = 0.30

$A_g = 125663.706$

$f_c' = 33.00$

$N = 4770.03$

$E_c \cdot I_g = 3.3929E+013$

Calculation of Yielding Moment My

Calculation of δ / y and My according to (7) - (8) in Biskinis and Fardis

$My = \text{Min}(My_{ten}, My_{com}) = 3.0318E+008$

y ((10a) or (10b)) = 1.6222681E-005

My_{ten} (8a) = 3.0318E+008

δ_{ten} (7a) = 69.35398

error of function (7a) = 0.00743251

My_{com} (8b) = 4.6746E+008

δ_{com} (7b) = 67.1564

error of function (7b) = -0.0026554

with $e_y = 0.0027778$

$e_{co} = 0.002$

$\alpha_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)

$d_1 = 44.00$

$R = 200.00$

$v = 0.00102233$

$N = 4770.03$

$A_c = 125663.706$

$\rho = 0.36359274$

with f_c^* ((12.3), ACI 440) = 37.12975

$f_c = 33.00$

$f_l = 1.3173$

$k = 1$

Effective FRP thickness, $tf = NL \cdot t \cdot \cos(b1) = 1.016$

e_{fe} ((12.5) and (12.7)) = 0.004

$E_f = 64828.00$

Calculation of ratio I_b / I_d

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

End Of Calculation of Shear Capacity for element: column CC1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 10

column C1, Floor 1

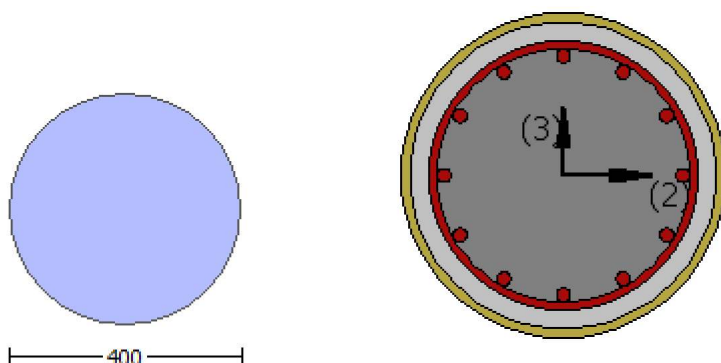
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ)

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rccs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.56406
 Element Length, L = 3000.00
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{ou}, \min > 1$)
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, t = 1.016
 Tensile Strength, f_{fu} = 1055.00
 Tensile Modulus, E_f = 64828.00
 Elongation, ϵ_{fu} = 0.01
 Number of directions, NoDir = 1
 Fiber orientations, bi: 0.00°
 Number of layers, NL = 1
 Radius of rounding corners, R = 40.00

Stepwise Properties

At local axis: 3
 EDGE -A-
 Shear Force, V_a = 1.1167452E-031
 EDGE -B-
 Shear Force, V_b = -1.1167452E-031
 BOTH EDGES
 Axial Force, F = -4771.233
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: A_{st} = 0.00
 -Compression: A_{sc} = 3053.628
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{st,ten}$ = 1017.876
 -Compression: $A_{st,com}$ = 1017.876
 -Middle: $A_{st,mid}$ = 1017.876

Calculation of Shear Capacity ratio, V_e/V_r = 0.44725617
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 202038.041$
 with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 3.0306E+008$
 $\mu_{u1+} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u1-} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 3.0306E+008$
 $\mu_{u2+} = 3.0306E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u2-} = 3.0306E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of μ_{u1+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ_u
 $\mu_u = 3.0306E+008$

= 1.02974
 ' = 0.91217079
 error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 51.61391$
 conf. factor $c = 1.56406$
 $f_c = 33.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/d

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

Calculation of μ_1 -

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 3.0306E+008$

$= 1.02974$
 $' = 0.91217079$
 error of function (3.68), Biskinis Phd = 60360.02
 From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 51.61391$
 conf. factor $c = 1.56406$
 $f_c = 33.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/d

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

Calculation of μ_2 +

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 3.0306E+008$

$= 1.02974$
 $' = 0.91217079$
 error of function (3.68), Biskinis Phd = 60360.02
 From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 51.61391$
 conf. factor $c = 1.56406$
 $f_c = 33.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$

$$A_c = 125663.706$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of μ_2

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 3.0306 \times 10^8$

$$= 1.02974$$

$$\rho' = 0.91217079$$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 51.61391$

conf. factor $c = 1.56406$

$f_c = 33.00$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00101663$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 451727.786$

Calculation of Shear Strength at edge 1, $V_{r1} = 451727.786$

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

$V_{ColO} = 451727.786$

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

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

$$= 1 \text{ (normal-weight concrete)}$$

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

$$M/Vd = 2.00$$

$$\mu_u = 1.5353150 \times 10^{-11}$$

$$V_u = 1.1167452 \times 10^{-31}$$

$$d = 0.8 \cdot D = 320.00$$

$$N_u = 4771.233$$

$$A_g = 125663.706$$

From (11.5.4.8), ACI 318-14: $V_s = 219326.297$

$$A_v = \rho_s \cdot A_{stirrup} = 123370.055$$

$$f_y = 555.56$$

$$s = 100.00$$

V_s is multiplied by $Col = 0.00$

$$s/d = 0.3125$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 194961.134$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$$w_f/s_f = 1 \text{ (FRP strips adjacent to one another).}$$

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \alpha_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 370.00
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 306911.784$
 $b_w * d = \rho * d^2 / 4 = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 451727.786$
 $V_{r2} = V_{Col}((10.3), \text{ASCE 41-17}) = k_n l * V_{Col0}$
 $V_{Col0} = 451727.786$
 $k_n l = 1$ (zero step-static loading)

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

$\rho = 1$ (normal-weight concrete)
 $f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M / V d = 2.00$
 $\mu_u = 1.5353150E-011$
 $\nu_u = 1.1167452E-031$
 $d = 0.8 * D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 219326.297$
 $A_v = \rho / 2 * A_{stirrup} = 123370.055$
 $f_y = 555.56$
 $s = 100.00$
 V_s is multiplied by $\rho_{Col} = 0.00$
 $s / d = 0.3125$
 $V_f((11-3)-(11.4), \text{ACI 440}) = 194961.134$
 $f = 0.95$, for fully-wrapped sections
 $w_f / s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \alpha_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 370.00
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 306911.784$
 $b_w * d = \rho * d^2 / 4 = 80424.772$

End Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1
 At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rccs

Constant Properties

Knowledge Factor, $\phi = 0.90$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.56406

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = -6.8378665E-048$

EDGE -B-

Shear Force, $V_b = 6.8378665E-048$

BOTH EDGES

Axial Force, $F = -4771.233$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{slt} = 0.00$

-Compression: $A_{slc} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1017.876$

-Compression: $A_{sl,com} = 1017.876$

-Middle: $A_{sl,mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.44725617$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 202038.041$

with

$M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 3.0306E+008$

$\mu_{u1+} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{u1-} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 3.0306\text{E}+008$$

$M_{u2+} = 3.0306\text{E}+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 3.0306\text{E}+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of M_{u1+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), M_u
 $M_u = 3.0306\text{E}+008$

$$\begin{aligned} &= 1.02974 \\ &\phi = 0.91217079 \\ &\text{error of function (3.68), Biskinis Phd} = 60360.02 \\ &\text{From 5A.2, TB DY: } f_{cc} = f_c \cdot c = 51.61391 \\ &\text{conf. factor } c = 1.56406 \\ &f_c = 33.00 \\ &\text{From 10.3.5, ASCE41-17, Final value of } f_y: f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45 \\ &l_b/d = 1.00 \\ &d_1 = 44.00 \\ &R = 200.00 \\ &v = 0.00101663 \\ &N = 4771.233 \\ &A_c = 125663.706 \\ &= \phi \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585 \end{aligned}$$

Calculation of ratio l_b/d

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

Calculation of M_{u1-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), M_u
 $M_u = 3.0306\text{E}+008$

$$\begin{aligned} &= 1.02974 \\ &\phi = 0.91217079 \\ &\text{error of function (3.68), Biskinis Phd} = 60360.02 \\ &\text{From 5A.2, TB DY: } f_{cc} = f_c \cdot c = 51.61391 \\ &\text{conf. factor } c = 1.56406 \\ &f_c = 33.00 \\ &\text{From 10.3.5, ASCE41-17, Final value of } f_y: f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45 \\ &l_b/d = 1.00 \\ &d_1 = 44.00 \\ &R = 200.00 \\ &v = 0.00101663 \\ &N = 4771.233 \\ &A_c = 125663.706 \\ &= \phi \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585 \end{aligned}$$

Calculation of ratio l_b/d

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

Calculation of M_{u2+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02
From 5A.2, TBDY: fcc = fc* c = 51.61391
conf. factor c = 1.56406
fc = 33.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 694.45
lb/d = 1.00
d1 = 44.00
R = 200.00
v = 0.00101663
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.45184585

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02
From 5A.2, TBDY: fcc = fc* c = 51.61391
conf. factor c = 1.56406
fc = 33.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 694.45
lb/d = 1.00
d1 = 44.00
R = 200.00
v = 0.00101663
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.45184585

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 451727.786

Calculation of Shear Strength at edge 1, Vr1 = 451727.786
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VColO
VColO = 451727.786
knl = 1 (zero step-static loading)

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

$\lambda = 1$ (normal-weight concrete)
 $f'_c = 33.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 5.4715235E-012$
 $\mu_v = 6.8378665E-048$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 219326.297$
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 555.56$
 $s = 100.00$
 V_s is multiplied by $\lambda = 1.00$
 $s/d = 0.3125$
 V_f ((11-3)-(11.4), ACI 440) = 194961.134
 $\lambda = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin^2 + \cos^2$ is replaced with $(\cot^2 + \cot^2) \sin^2 \alpha$ which is more a generalised expression,
 where α is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\alpha = 45^\circ$
 $V_f = \min(|V_f(45, \lambda)|, |V_f(-45, \lambda)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{Dir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 370.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $\epsilon_f = 0.004$, from (11.6a), ACI 440
 with $\epsilon_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 306911.784$
 $b_w \cdot d = \lambda \cdot d^2 / 4 = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 451727.786$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $\lambda \cdot V_{Col0}$
 $V_{Col0} = 451727.786$
 $\lambda = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + \lambda \cdot V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)
 $f'_c = 33.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 5.4715235E-012$
 $\mu_v = 6.8378665E-048$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 219326.297$
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 555.56$
 $s = 100.00$
 V_s is multiplied by $\lambda = 1.00$
 $s/d = 0.3125$
 V_f ((11-3)-(11.4), ACI 440) = 194961.134
 $\lambda = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin^2 + \cos^2$ is replaced with $(\cot^2 + \cot^2) \sin^2 \alpha$ which is more a generalised expression,
 where α is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\alpha = 45^\circ$
 $V_f = \min(|V_f(45, \lambda)|, |V_f(-45, \lambda)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{Dir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 370.00
 f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 306911.784$

$b_w \cdot d = \frac{1}{4} \cdot d^2 = 80424.772$

End Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column CC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rccs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/l_d \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $N_{dir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 5.1473654E-010$

Shear Force, $V_2 = -3007.62$

Shear Force, $V_3 = -1.5929820E-013$

Axial Force, $F = -4770.03$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 1272.345$

-Compression: $A_{sl,c} = 1781.283$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1017.876$

-Compression: $A_{sl,com} = 1017.876$

-Middle: $A_{sl,mid} = 1017.876$

Mean Diameter of Tension Reinforcement, $Db_L = 18.00$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = 1.0^*$ $u = 0.0864352$
 $u = y + p = 0.0864352$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.01489311$ ((4.29), Biskinis Phd))
 $M_y = 3.0318E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.0179E+013$
 $factor = 0.30$
 $A_g = 125663.706$
 $f_c' = 33.00$
 $N = 4770.03$
 $E_c * I_g = 3.3929E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to (7) - (8) in Biskinis and Fardis

$M_y = \min(M_{y_ten}, M_{y_com}) = 3.0318E+008$
 y ((10a) or (10b)) = $1.6222681E-005$
 M_{y_ten} (8a) = $3.0318E+008$
 y_{ten} (7a) = 69.35398
error of function (7a) = 0.00743251
 M_{y_com} (8b) = $4.6746E+008$
 y_{com} (7b) = 67.1564
error of function (7b) = -0.0026554
with $e_y = 0.0027778$
 $e_{co} = 0.002$
 $apl = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00102233$
 $N = 4770.03$
 $A_c = 125663.706$
 $= 0.36359274$
with $f_c' = 33.00$
 $f_l = 1.3173$
 $k = 1$
Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $E_f = 64828.00$

Calculation of ratio l_b/d

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

- Calculation of p -

From table 10-9: $p = 0.07154209$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/d < 1$
shear control ratio $V_y E / V_{col} E = 0.44725617$
 $d = 0.00$
 $s = 0.00$
 $t = 2 * A_v / (d_c * s) + 4 * t_f / D * (f_{fe} / f_s) = 0.00$
 $A_v = 78.53982$, is the area of the circular stirrup
 $d_c = D - 2 * cover$ - Hoop Diameter = 340.00
The term $2 * t_f / bw * (f_{fe} / f_s)$ is implemented to account for FRP contribution
where $f = 2 * t_f / bw$ 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 = 4770.03

Ag = 125663.706

f_{cE} = 33.00

f_{ytE} = f_{ylE} = 555.56

pl = Area_Tot_Long_Rein/(Ag) = 0.0243

f_{cE} = 33.00

End Of Calculation of Chord Rotation Capacity for element: column CC1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 11

column C1, Floor 1

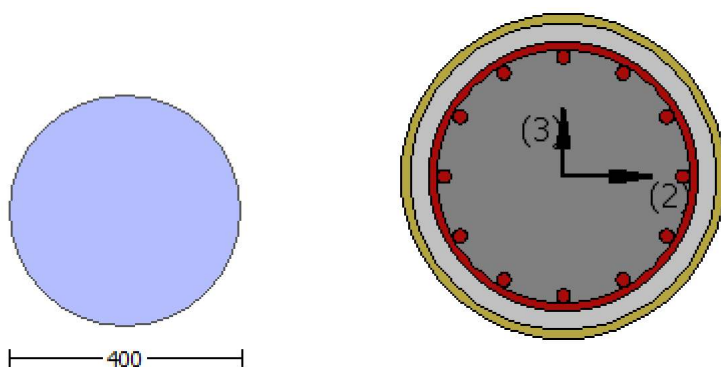
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column CC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rccs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

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

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

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

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = 5.1473654E-010$

Shear Force, $V_a = -1.5929820E-013$

EDGE -B-

Bending Moment, $M_b = -3.6626908E-011$

Shear Force, $V_b = 1.5929820E-013$

BOTH EDGES

Axial Force, $F = -4770.03$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 1272.345$

-Compression: $As_c = 1781.283$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1017.876$

-Compression: $As_{l,com} = 1017.876$

-Middle: $As_{l,mid} = 1017.876$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.00$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0 \cdot V_n = 393301.141$

V_n ((10.3), ASCE 41-17) = $kn_l \cdot V_{CoIO} = 393301.141$

$V_{CoI} = 393301.141$

$kn_l = 1.00$

displacement_ductility_demand = 0.00

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

= 1 (normal-weight concrete)

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

$M/Vd = 2.00$

$M_u = 5.1473654E-010$

$V_u = 1.5929820E-013$

$d = 0.8 \cdot D = 320.00$

$N_u = 4770.03$

$A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 197392.088$
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 500.00$
 $s = 100.00$
 V_s is multiplied by $\text{Col} = 0.00$
 $s/d = 0.3125$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 194961.134$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation θ_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 370.00
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 267132.42$
 $b_w \cdot d = \sqrt{2} \cdot d^2 / 4 = 80424.772$

displacement_ductility_demand is calculated as δ / y

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

From analysis, chord rotation $\theta = 1.5070001\text{E-}020$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.01489311$ ((4.29), Biskinis Phd))
 $M_y = 3.0318\text{E+}008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 1.0179\text{E+}013$
 factor = 0.30
 $A_g = 125663.706$
 $f_c' = 33.00$
 $N = 4770.03$
 $E_c \cdot I_g = 3.3929\text{E+}013$

Calculation of Yielding Moment M_y

Calculation of δ and M_y according to (7) - (8) in Biskinis and Fardis

$M_y = \text{Min}(M_{y_ten}, M_{y_com}) = 3.0318\text{E+}008$
 $y ((10a) \text{ or } (10b)) = 1.6222681\text{E-}005$
 $M_{y_ten} (8a) = 3.0318\text{E+}008$
 $\delta_{ten} (7a) = 69.35398$
 error of function (7a) = 0.00743251
 $M_{y_com} (8b) = 4.6746\text{E+}008$
 $\delta_{com} (7b) = 67.1564$
 error of function (7b) = -0.0026554
 with $e_y = 0.0027778$
 $e_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00102233$
 $N = 4770.03$
 $A_c = 125663.706$
 $= 0.36359274$
 with f_c^* ((12.3), ACI 440) = 37.12975

$f_c = 33.00$
 $f_l = 1.3173$
 $k = 1$
 Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 $e_{fe} ((12.5) \text{ and } (12.7)) = 0.004$
 $E_f = 64828.00$

Calculation of ratio I_b/I_d

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

End Of Calculation of Shear Capacity for element: column CC1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 12

column C1, Floor 1

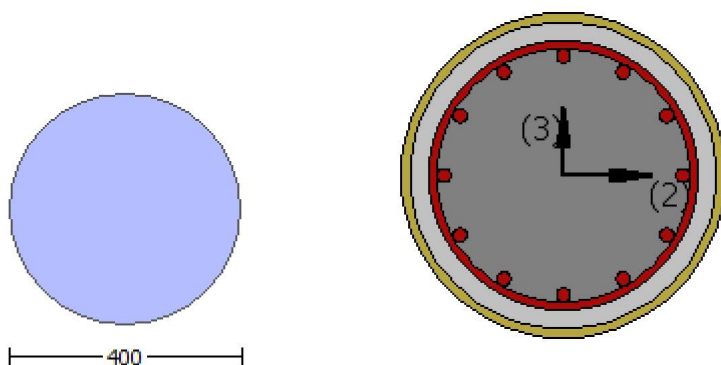
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (μ)

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rccs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$
 #####
 Diameter, $D = 400.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.56406
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{ou}, \min \geq 1$)
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $NoDir = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
 EDGE -A-
 Shear Force, $V_a = 1.1167452E-031$
 EDGE -B-
 Shear Force, $V_b = -1.1167452E-031$
 BOTH EDGES
 Axial Force, $F = -4771.233$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 0.00$
 -Compression: $As_c = 3053.628$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{t,ten} = 1017.876$
 -Compression: $As_{l,com} = 1017.876$
 -Middle: $As_{l,mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.44725617$
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 202038.041$
 with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 3.0306E+008$
 $\mu_{u1+} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
 which is defined for the static loading combination
 $\mu_{u1-} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
 direction which is defined for the static loading combination
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 3.0306E+008$
 $\mu_{u2+} = 3.0306E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
 which is defined for the the static loading combination
 $\mu_{u2-} = 3.0306E+008$, 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 Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02
From 5A.2, TBDY: fcc = fc* c = 51.61391
conf. factor c = 1.56406
fc = 33.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 694.45
lb/d = 1.00
d1 = 44.00
R = 200.00
v = 0.00101663
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.45184585

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02
From 5A.2, TBDY: fcc = fc* c = 51.61391
conf. factor c = 1.56406
fc = 33.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 694.45
lb/d = 1.00
d1 = 44.00
R = 200.00
v = 0.00101663
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.45184585

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TBDY: $f_{cc} = f_c' \cdot c = 51.61391$
 conf. factor $c = 1.56406$
 $f_c = 33.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/d

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

Calculation of μ_2 -

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 3.0306E+008$

$= 1.02974$
 $' = 0.91217079$
 error of function (3.68), Biskinis Phd = 60360.02
 From 5A.2, TBDY: $f_{cc} = f_c' \cdot c = 51.61391$
 conf. factor $c = 1.56406$
 $f_c = 33.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 451727.786$

Calculation of Shear Strength at edge 1, $V_{r1} = 451727.786$
 $V_{r1} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = k_{nl} \cdot V_{CoI0}$
 $V_{CoI0} = 451727.786$
 $k_{nl} = 1$ (zero step-static loading)

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

$= 1$ (normal-weight concrete)
 $f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu = 1.5353150E-011$
 $V_u = 1.1167452E-031$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 219326.297$

$A_v = \frac{1}{2} A_{stirrup} = 123370.055$

$f_y = 555.56$

$s = 100.00$

V_s is multiplied by $\text{Col} = 0.00$

$s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 194961.134

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation θ_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 306911.784$

$b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 451727.786$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n \cdot V_{Col0}$

$V_{Col0} = 451727.786$

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

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

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

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

$M/Vd = 2.00$

$\mu_u = 1.5353150E-011$

$\nu_u = 1.1167452E-031$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 219326.297$

$A_v = \frac{1}{2} A_{stirrup} = 123370.055$

$f_y = 555.56$

$s = 100.00$

V_s is multiplied by $\text{Col} = 0.00$

$s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 194961.134

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation θ_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 306911.784$

$b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 80424.772$

End Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rccs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.56406

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = -6.8378665E-048$

EDGE -B-

Shear Force, $V_b = 6.8378665E-048$

BOTH EDGES

Axial Force, $F = -4771.233$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1017.876$

-Compression: $As_{l,com} = 1017.876$

-Middle: $As_{l,mid} = 1017.876$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.44725617$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 202038.041$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 3.0306E+008$

$M_{u1+} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 3.0306E+008$

$M_{u2+} = 3.0306E+008$, 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

$M_{u2-} = 3.0306E+008$, 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 Moment Strength ((3.67), Biskinis Phd), M_u

$M_u = 3.0306E+008$

 $\phi = 1.02974$

$\phi' = 0.91217079$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TBDY: $f_{cc} = f_c^* \quad c = 51.61391$

conf. factor $c = 1.56406$

$f_c = 33.00$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 200.00$

$v = 0.00101663$

$N = 4771.233$

$A_c = 125663.706$

$= \phi \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/d

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

Calculation of M_{u1-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), M_u

$M_u = 3.0306E+008$

 $\phi = 1.02974$

$\phi' = 0.91217079$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TBDY: $f_{cc} = f_c^* \quad c = 51.61391$

conf. factor $c = 1.56406$

$f_c = 33.00$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 200.00$

$v = 0.00101663$

$N = 4771.233$

$A_c = 125663.706$

$= \phi \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/d

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

Calculation of μ_{2+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 3.0306E+008$

$$= 1.02974$$

$$' = 0.91217079$$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 51.61391$

conf. factor $c = 1.56406$

$$f_c = 33.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00101663$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of μ_{2-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 3.0306E+008$

$$= 1.02974$$

$$' = 0.91217079$$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 51.61391$

conf. factor $c = 1.56406$

$$f_c = 33.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00101663$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 451727.786$

Calculation of Shear Strength at edge 1, $V_{r1} = 451727.786$

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

$V_{Col0} = 451727.786$

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

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

$= 1$ (normal-weight concrete)

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

$M/Vd = 2.00$

$\mu_u = 5.4715235E-012$

$\nu_u = 6.8378665E-048$

$d = 0.8 * D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 219326.297$

$A_v = /2 * A_{stirrup} = 123370.055$

$f_y = 555.56$

$s = 100.00$

V_s is multiplied by $Col = 0.00$

$s/d = 0.3125$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 194961.134$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(,)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $= 45^\circ$ and $= -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $1 = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 306911.784$

$b_w * d = *d * d / 4 = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 451727.786$

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

$V_{Col0} = 451727.786$

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

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

$= 1$ (normal-weight concrete)

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

$M/Vd = 2.00$

$\mu_u = 5.4715235E-012$

$\nu_u = 6.8378665E-048$

$d = 0.8 * D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 219326.297$

$A_v = /2 * A_{stirrup} = 123370.055$

$f_y = 555.56$

$s = 100.00$

V_s is multiplied by $Col = 0.00$

$s/d = 0.3125$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 194961.134$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 370.00
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 306911.784$
 $b_w \cdot d = \sqrt{d} \cdot d / 4 = 80424.772$

End Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1
 At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column CC1 of floor 1
 At local axis: 3
 Integration Section: (a)
 Section Type: rccs

Constant Properties

Knowledge Factor, $\gamma = 0.90$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$
 Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$
 Diameter, $D = 400.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_b / l_d \geq 1$)
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $\text{NoDir} = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -9.0263E+006$
 Shear Force, $V_2 = -3007.62$
 Shear Force, $V_3 = -1.5929820E-013$
 Axial Force, $F = -4770.03$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{st} = 1272.345$

-Compression: $Asl_c = 1781.283$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $Asl_{ten} = 1017.876$
 -Compression: $Asl_{com} = 1017.876$
 -Middle: $Asl_{mid} = 1017.876$
 Mean Diameter of Tension Reinforcement, $DbL = 18.00$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = 1.0^*$ $u = 0.10133974$
 $u = y + p = 0.10133974$

- Calculation of y -

$y = (My * L_s / 3) / E_{eff} = 0.02979765$ ((4.29), Biskinis Phd))
 $My = 3.0318E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3001.151
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.0179E+013$
 $factor = 0.30$
 $A_g = 125663.706$
 $f_c' = 33.00$
 $N = 4770.03$
 $E_c * I_g = 3.3929E+013$

Calculation of Yielding Moment My

Calculation of y and My according to (7) - (8) in Biskinis and Fardis

$My = \min(My_{ten}, My_{com}) = 3.0318E+008$
 y ((10a) or (10b)) = 1.6222681E-005
 My_{ten} (8a) = 3.0318E+008
 $_{ten}$ (7a) = 69.35398
 error of function (7a) = 0.00743251
 My_{com} (8b) = 4.6746E+008
 $_{com}$ (7b) = 67.1564
 error of function (7b) = -0.0026554
 with $e_y = 0.0027778$
 $e_{co} = 0.002$
 $apl = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d1 = 44.00$
 $R = 200.00$
 $v = 0.00102233$
 $N = 4770.03$
 $A_c = 125663.706$
 $= 0.36359274$
 with f_c^* ((12.3), ACI 440) = 37.12975
 $f_c = 33.00$
 $f_l = 1.3173$
 $k = 1$
 Effective FRP thickness, $t_f = NL * t * \cos(b1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $E_f = 64828.00$

Calculation of ratio l_b / l_d

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

- Calculation of p -

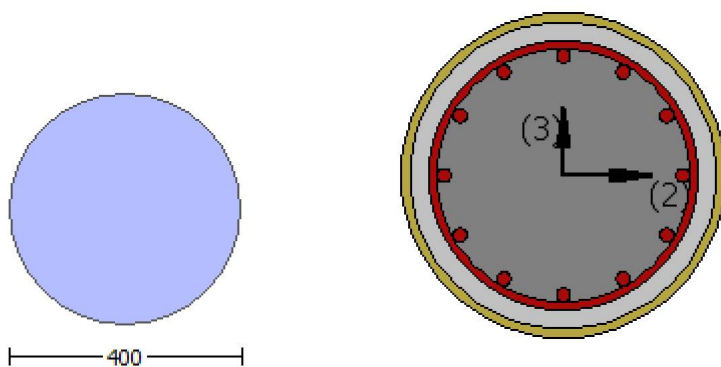
From table 10-9: $p = 0.07154209$
 with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$
 shear control ratio $V_{yE}/V_{ColOE} = 0.44725617$
 $d = 0.00$
 $s = 0.00$
 $t = 2 \cdot A_v / (d_c \cdot s) + 4 \cdot t_f / D \cdot (f_{fe} / f_s) = 0.00$
 $A_v = 78.53982$, is the area of the circular stirrup
 $d_c = D - 2 \cdot \text{cover} - \text{Hoop Diameter} = 340.00$
 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.
 $N_{UD} = 4770.03$
 $A_g = 125663.706$
 $f_{cE} = 33.00$
 $f_{yE} = f_{yIE} = 555.56$
 $\rho_l = \text{Area_Tot_Long_Rein} / (A_g) = 0.0243$
 $f_{cE} = 33.00$

 End Of Calculation of Chord Rotation Capacity for element: column CC1 of floor 1
 At local axis: 3
 Integration Section: (a)

Calculation No. 13

column C1, Floor 1
 Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)
 Analysis: Uniform +X
 Check: Shear capacity V_{Rd}
 Edge: End
 Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column CC1 of floor 1
 At local axis: 2
 Integration Section: (b)
 Section Type: rccs
 Constant Properties

Knowledge Factor, $\gamma = 0.90$
 Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.
 Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$
 Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of γ for displacement ductility demand,
 the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as
 Deformation-Controlled Action (Table C7-1, ASCE41-17).
 New material: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material: Steel Strength, $f_s = f_{sm} = 555.56$
 #####
 Diameter, $D = 400.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{ou,min} = l_b/d \geq 1$)
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $\epsilon_{fu} = 0.01$
 Number of directions, $N_{oDir} = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $N_L = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = -9.0263E+006$
 Shear Force, $V_a = -3007.62$
 EDGE -B-
 Bending Moment, $M_b = 0.0481749$
 Shear Force, $V_b = 3007.62$
 BOTH EDGES
 Axial Force, $F = -4770.03$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{sl,t} = 0.00$
 -Compression: $A_{sl,c} = 3053.628$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{sl,ten} = 1017.876$
 -Compression: $A_{sl,com} = 1017.876$
 -Middle: $A_{sl,mid} = 1017.876$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.00$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0 \cdot V_n = 393301.141$
 $V_n ((10.3), ASCE 41-17) = knl \cdot V_{CoIO} = 393301.141$
 $V_{CoI} = 393301.141$
 $knl = 1.00$
 $displacement_ductility_demand = 0.04465363$

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d/s$ ' is replaced by ' $V_{s+} = f \cdot V_f$ '

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

= 1 (normal-weight concrete)

$f'_c = 25.00$, but $f'_c \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 0.0481749$

$V_u = 3007.62$

$d = 0.8 \cdot D = 320.00$

$N_u = 4770.03$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 197392.088$

$A_v = \frac{1}{2} A_{\text{stirrup}} = 123370.055$

$f_y = 500.00$

$s = 100.00$

V_s is multiplied by $\text{Col} = 0.00$

$s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 194961.134

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\alpha_1 = \alpha_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 267132.42$

$b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 80424.772$

displacement ductility demand is calculated as δ_u / y

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

From analysis, chord rotation $\theta = 0.00013301$

$y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00297862$ ((4.29), Biskinis Phd))

$M_y = 3.0318\text{E}+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00

From table 10.5, ASCE 41_17: $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 1.0179\text{E}+013$

factor = 0.30

$A_g = 125663.706$

$f'_c = 33.00$

$N = 4770.03$

$E_c \cdot I_g = 3.3929\text{E}+013$

Calculation of Yielding Moment M_y

Calculation of δ_u and M_y according to (7) - (8) in Biskinis and Fardis

$M_y = \text{Min}(M_{y_{\text{ten}}}, M_{y_{\text{com}}}) = 3.0318\text{E}+008$

y ((10a) or (10b)) = 1.6222681E-005

$M_{y_{\text{ten}}} (8a) = 3.0318\text{E}+008$

$_{\text{ten}} (7a) = 69.35398$

error of function (7a) = 0.00743251

$M_{y_{\text{com}}} (8b) = 4.6746\text{E}+008$

$_{\text{com}} (7b) = 67.1564$

error of function (7b) = -0.0026554

with $e_y = 0.0027778$

$e_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00102233$
 $N = 4770.03$
 $A_c = 125663.706$
 $= 0.36359274$
 with f_c^* ((12.3), ACI 440) = 37.12975
 $f_c = 33.00$
 $f_l = 1.3173$
 $k = 1$
 Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $E_f = 64828.00$

Calculation of ratio l_b/d

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

End Of Calculation of Shear Capacity for element: column CC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 14

column C1, Floor 1

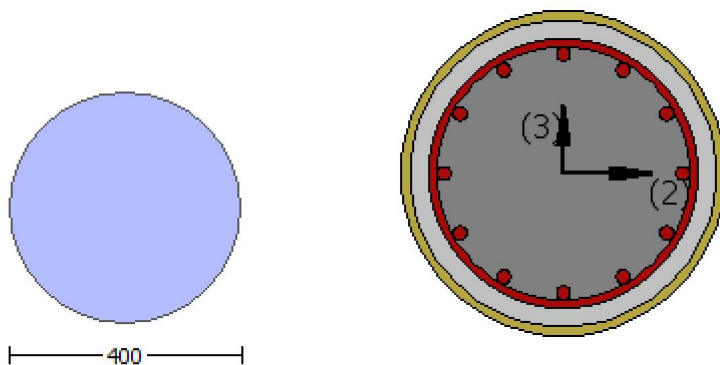
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ)

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rccs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.56406

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 1.1167452E-031$

EDGE -B-

Shear Force, $V_b = -1.1167452E-031$

BOTH EDGES

Axial Force, $F = -4771.233$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1017.876$

-Compression: $A_{sl,com} = 1017.876$

-Middle: $A_{sl,mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.44725617$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 202038.041$

with

$M_{pr1} = \max(M_{u1+}, M_{u1-}) = 3.0306E+008$

$M_{u1+} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment

direction which is defined for the static loading combination

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 3.0306E+008$$

$M_{u2+} = 3.0306E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 3.0306E+008$, 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 Moment Strength ((3.67), Biskinis Phd), M_u
 $M_u = 3.0306E+008$

$$= 1.02974$$

$$\lambda = 0.91217079$$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TB DY: $f_{cc} = f_c \cdot \lambda = 51.61391$

$$\text{conf. factor } \lambda = 1.56406$$

$$f_c = 33.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00101663$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \lambda \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of M_{u1-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), M_u
 $M_u = 3.0306E+008$

$$= 1.02974$$

$$\lambda = 0.91217079$$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TB DY: $f_{cc} = f_c \cdot \lambda = 51.61391$

$$\text{conf. factor } \lambda = 1.56406$$

$$f_c = 33.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00101663$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \lambda \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of M_{u2+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02
From 5A.2, TBDY: fcc = fc* c = 51.61391
conf. factor c = 1.56406
fc = 33.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 694.45
lb/d = 1.00
d1 = 44.00
R = 200.00
v = 0.00101663
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.45184585

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02
From 5A.2, TBDY: fcc = fc* c = 51.61391
conf. factor c = 1.56406
fc = 33.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 694.45
lb/d = 1.00
d1 = 44.00
R = 200.00
v = 0.00101663
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.45184585

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 451727.786

Calculation of Shear Strength at edge 1, Vr1 = 451727.786

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

VColO = 451727.786

knl = 1 (zero step-static loading)

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

$\lambda = 1$ (normal-weight concrete)
 $f'_c = 33.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 1.5353150E-011$
 $\mu_v = 1.1167452E-031$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 219326.297$
 $A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 123370.055$
 $f_y = 555.56$
 $s = 100.00$
 V_s is multiplied by $\text{Col} = 0.00$
 $s/d = 0.3125$
 $V_f ((11-3)-(11.4), \text{ACI 440}) = 194961.134$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 370.00
 $f_{fe} ((11-5), \text{ACI 440}) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 306911.784$
 $b_w \cdot d = \sqrt{4} \cdot d = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 451727.786$
 $V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE 41-17}) = k_{nl} \cdot V_{\text{Col}0}$
 $V_{\text{Col}0} = 451727.786$
 $k_{nl} = 1$ (zero step-static loading)

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

$\lambda = 1$ (normal-weight concrete)
 $f'_c = 33.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 1.5353150E-011$
 $\mu_v = 1.1167452E-031$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 219326.297$
 $A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 123370.055$
 $f_y = 555.56$
 $s = 100.00$
 V_s is multiplied by $\text{Col} = 0.00$
 $s/d = 0.3125$
 $V_f ((11-3)-(11.4), \text{ACI 440}) = 194961.134$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

```

ffe ((11-5), ACI 440) = 259.312
Ef = 64828.00
fe = 0.004, from (11.6a), ACI 440
with fu = 0.01
From (11-11), ACI 440: Vs + Vf <= 306911.784
bw*d = *d*d/4 = 80424.772
-----

End Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1
At local axis: 3
-----

Start Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rccs

Constant Properties
-----
Knowledge Factor, k = 0.90
Mean strength values are used for both shear and moment calculations.
Consequently:
New material of Secondary Member: Concrete Strength, fc = fcm = 33.00
New material of Secondary Member: Steel Strength, fs = fsm = 555.56
Concrete Elasticity, Ec = 26999.444
Steel Elasticity, Es = 200000.00
#####
Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
New material: Steel Strength, fs = 1.25*fsm = 694.45
#####
Diameter, D = 400.00
Cover Thickness, c = 25.00
Mean Confinement Factor overall section = 1.56406
Element Length, L = 3000.00
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length (lo/lou, min >= 1)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, ffu = 1055.00
Tensile Modulus, Ef = 64828.00
Elongation, efu = 0.01
Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00
-----

Stepwise Properties
-----
At local axis: 2
EDGE -A-
Shear Force, Va = -6.8378665E-048
EDGE -B-
Shear Force, Vb = 6.8378665E-048
BOTH EDGES
Axial Force, F = -4771.233
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00

```

-Compression: $Asl_c = 3053.628$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $Asl_{ten} = 1017.876$
-Compression: $Asl_{com} = 1017.876$
-Middle: $Asl_{mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.44725617$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 202038.041$
with

$M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 3.0306E+008$

$\mu_{u1+} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{u1-} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 3.0306E+008$

$\mu_{u2+} = 3.0306E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{u2-} = 3.0306E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of μ_{u1+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ_u
 $\mu_u = 3.0306E+008$

$$= 1.02974$$

$$\lambda = 0.91217079$$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TB DY: $f_{cc} = f_c^* \quad c = 51.61391$

conf. factor $c = 1.56406$

$$f_c = 33.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00101663$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \lambda \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of μ_{u1-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ_u
 $\mu_u = 3.0306E+008$

$$= 1.02974$$

$$\lambda = 0.91217079$$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TB DY: $f_{cc} = f_c^* \quad c = 51.61391$

conf. factor $c = 1.56406$

$$f_c = 33.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00101663$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of μ_{2+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ

$$\mu = 3.0306E+008$$

$$= 1.02974$$

$$' = 0.91217079$$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 51.61391$

$$\text{conf. factor } c = 1.56406$$

$$f_c = 33.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00101663$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of μ_{2-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ

$$\mu = 3.0306E+008$$

$$= 1.02974$$

$$' = 0.91217079$$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 51.61391$

$$\text{conf. factor } c = 1.56406$$

$$f_c = 33.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00101663$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 451727.786$

Calculation of Shear Strength at edge 1, $V_{r1} = 451727.786$

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

$V_{Col0} = 451727.786$

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

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

$= 1$ (normal-weight concrete)

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

$M/Vd = 2.00$

$\mu_u = 5.4715235E-012$

$\nu_u = 6.8378665E-048$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 219326.297$

$A_v = \frac{1}{2} \cdot A_{\text{stirrup}} = 123370.055$

$f_y = 555.56$

$s = 100.00$

V_s is multiplied by $\text{Col} = 0.00$

$s/d = 0.3125$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 194961.134$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 306911.784$

$b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 451727.786$

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

$V_{Col0} = 451727.786$

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

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

$= 1$ (normal-weight concrete)

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

$M/Vd = 2.00$

$\mu_u = 5.4715235E-012$

$\nu_u = 6.8378665E-048$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 219326.297$

$A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 123370.055$

$f_y = 555.56$

$s = 100.00$

V_s is multiplied by $\text{Col} = 0.00$

$s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 194961.134

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 306911.784$

$b_w \cdot d = \pi \cdot d^2 / 4 = 80424.772$

End Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column CC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rccs

Constant Properties

Knowledge Factor, $\phi = 0.90$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{\text{Dir}} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -3.6626908\text{E-}011$

Shear Force, $V2 = 3007.62$

Shear Force, $V3 = 1.5929820\text{E-}013$

Axial Force, $F = -4770.03$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1017.876$

-Compression: $As_{l,com} = 1017.876$

-Middle: $As_{l,mid} = 1017.876$

Mean Diameter of Tension Reinforcement, $Db_L = 18.00$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = 1.0^*$ $u = 0.0864352$

$u = y + p = 0.0864352$

- Calculation of y -

$y = (My * L_s / 3) / E_{eff} = 0.01489311$ ((4.29), Biskinis Phd))

$My = 3.0318\text{E+}008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 1.0179\text{E+}013$

factor = 0.30

$A_g = 125663.706$

$f_c' = 33.00$

$N = 4770.03$

$E_c * I_g = 3.3929\text{E+}013$

Calculation of Yielding Moment My

Calculation of y and My according to (7) - (8) in Biskinis and Fardis

$My = \text{Min}(My_{ten}, My_{com}) = 3.0318\text{E+}008$

y ((10a) or (10b)) = 1.6222681E-005

My_{ten} (8a) = 3.0318E+008

y_{ten} (7a) = 69.35398

error of function (7a) = 0.00743251

My_{com} (8b) = 4.6746E+008

y_{com} (7b) = 67.1564

error of function (7b) = -0.0026554

with $e_y = 0.0027778$

$e_{co} = 0.002$

$a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)

$d_1 = 44.00$

$R = 200.00$

$v = 0.00102233$

$N = 4770.03$

$A_c = 125663.706$

= 0.36359274

with f_c^* ((12.3), ACI 440) = 37.12975

$f_c = 33.00$

$f_l = 1.3173$

$k = 1$

Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$

e_{fe} ((12.5) and (12.7)) = 0.004

$E_f = 64828.00$

Calculation of ratio l_b/l_d

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

- Calculation of ρ -

From table 10-9: $\rho = 0.07154209$

with:

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

shear control ratio $V_y E / V_{col} E = 0.44725617$

$d = 0.00$

$s = 0.00$

$t = 2 \cdot A_v / (d_c \cdot s) + 4 \cdot t_f / D \cdot (f_{fe} / f_s) = 0.00$

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

$d_c = D - 2 \cdot \text{cover} - \text{Hoop Diameter} = 340.00$

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.

$N_{UD} = 4770.03$

$A_g = 125663.706$

$f_{cE} = 33.00$

$f_{ytE} = f_{yIE} = 555.56$

$\rho_l = \text{Area_Tot_Long_Rein} / (A_g) = 0.0243$

$f_{cE} = 33.00$

End Of Calculation of Chord Rotation Capacity for element: column CC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 15

column C1, Floor 1

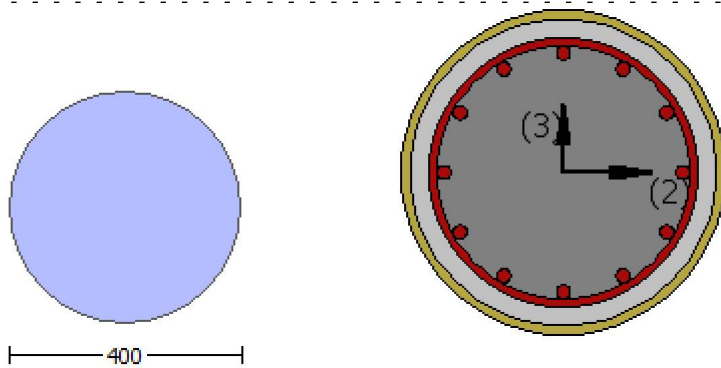
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column CC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rccs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

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

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

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

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = 5.1473654E-010$

Shear Force, $V_a = -1.5929820E-013$

EDGE -B-

Bending Moment, $M_b = -3.6626908E-011$

Shear Force, $V_b = 1.5929820E-013$

BOTH EDGES

Axial Force, $F = -4770.03$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1017.876$

-Compression: $As_{c,com} = 1017.876$

-Middle: $As_{mid} = 1017.876$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.00$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0 \cdot V_n = 393301.141$

V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{Col} = 393301.141$

$V_{Col} = 393301.141$

$k_n = 1.00$

$displacement_ductility_demand = 0.00$

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

= 1 (normal-weight concrete)

$f'_c = 25.00$, but $f'_c \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 3.6626908E-011$

$\nu_u = 1.5929820E-013$

$d = 0.8 \cdot D = 320.00$

$N_u = 4770.03$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 197392.088$

$A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$

$f_y = 500.00$

$s = 100.00$

V_s is multiplied by $\phi_{Col} = 0.00$

$s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 194961.134

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = 45^\circ$ and $\alpha = 90^\circ$

$V_f = \text{Min}(|V_f(45, 90)|, |V_f(-45, 90)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 267132.42$

$b_w \cdot d = \sqrt{2} \cdot d^2 / 4 = 80424.772$

$displacement_ductility_demand$ is calculated as δ / y

- Calculation of δ / y for END B -

for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 7.9508914E-021$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.01489311$ ((4.29), Biskinis Phd))

$M_y = 3.0318E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 1.0179E+013$

factor = 0.30
Ag = 125663.706
fc' = 33.00
N = 4770.03
Ec*Ig = 3.3929E+013

Calculation of Yielding Moment My

Calculation of ρ_y and My according to (7) - (8) in Biskinis and Fardis

My = Min(My_ten, My_com) = 3.0318E+008
 ρ_y ((10a) or (10b)) = 1.6222681E-005
My_ten (8a) = 3.0318E+008
 ρ_{y_ten} (7a) = 69.35398
error of function (7a) = 0.00743251
My_com (8b) = 4.6746E+008
 ρ_{y_com} (7b) = 67.1564
error of function (7b) = -0.0026554
with e_y = 0.0027778
 e_{co} = 0.002
 a_{pl} = 0.45 ((9c) in Biskinis and Fardis for FRP Wrap)
d1 = 44.00
R = 200.00
 v = 0.00102233
N = 4770.03
Ac = 125663.706
 ρ_{y_com} = 0.36359274
with f_c^* ((12.3), ACI 440) = 37.12975
fc = 33.00
fl = 1.3173
k = 1
Effective FRP thickness, t_f = NL*t*cos(b1) = 1.016
 e_{fe} ((12.5) and (12.7)) = 0.004
Ef = 64828.00

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

End Of Calculation of Shear Capacity for element: column CC1 of floor 1

At local axis: 3

Integration Section: (b)

Calculation No. 16

column C1, Floor 1

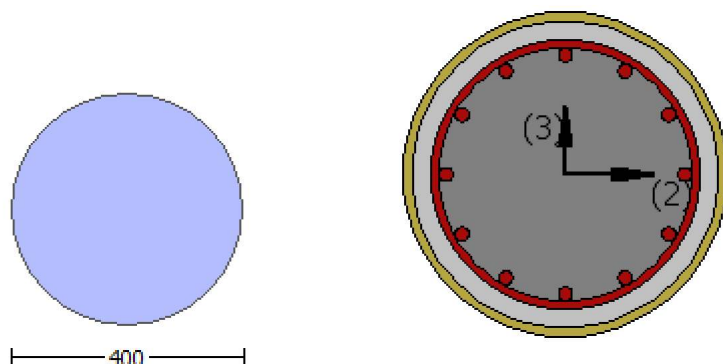
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rccs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.56406

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 1.1167452E-031$

EDGE -B-

Shear Force, $V_b = -1.1167452E-031$

BOTH EDGES

Axial Force, $F = -4771.233$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1017.876$

-Compression: $As_{c,com} = 1017.876$

-Middle: $As_{mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.44725617$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 202038.041$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 3.0306E+008$

$Mu_{1+} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 3.0306E+008$

$Mu_{2+} = 3.0306E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 3.0306E+008$, 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 Moment Strength ((3.67), Biskinis Phd), M_u

$M_u = 3.0306E+008$

$\phi = 1.02974$

$\phi' = 0.91217079$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TBDY: $f_{cc} = f_c' \cdot c = 51.61391$

conf. factor $c = 1.56406$

$f_c = 33.00$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 694.45$

$l_b/l_d = 1.00$

$d_1 = 44.00$

$R = 200.00$

$v = 0.00101663$

$N = 4771.233$

$A_c = 125663.706$

$= \phi' \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/l_d

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

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02
From 5A.2, TBDY: fcc = fc* c = 51.61391
conf. factor c = 1.56406
fc = 33.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 694.45
lb/d = 1.00
d1 = 44.00
R = 200.00
v = 0.00101663
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.45184585

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974
' = 0.91217079
error of function (3.68), Biskinis Phd = 60360.02
From 5A.2, TBDY: fcc = fc* c = 51.61391
conf. factor c = 1.56406
fc = 33.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 694.45
lb/d = 1.00
d1 = 44.00
R = 200.00
v = 0.00101663
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.45184585

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 3.0306E+008

= 1.02974

$\rho = 0.91217079$
 error of function (3.68), Biskinis Phd = 60360.02
 From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 51.61391$
 conf. factor $c = 1.56406$
 $f_c = 33.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 451727.786$

Calculation of Shear Strength at edge 1, $V_{r1} = 451727.786$

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

$V_{Col0} = 451727.786$

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

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

$= 1$ (normal-weight concrete)

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

$M/Vd = 2.00$

$\mu_u = 1.5353150E-011$

$\nu_u = 1.1167452E-031$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 219326.297$

$A_v = \frac{1}{2} \cdot A_{\text{stirrup}} = 123370.055$

$f_y = 555.56$

$s = 100.00$

V_s is multiplied by $\text{Col} = 0.00$

$s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 194961.134

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,

where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 306911.784$

$b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 451727.786$

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

VColO = 451727.786
knl = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)
 $f_c' = 33.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 1.5353150E-011$
 $V_u = 1.1167452E-031$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
From (11.5.4.8), ACI 318-14: $V_s = 219326.297$
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 555.56$
 $s = 100.00$
 V_s is multiplied by $\text{Col} = 0.00$
 $s/d = 0.3125$
 $V_f ((11-3)-(11.4), \text{ACI 440}) = 194961.134$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \alpha_1)|)$, with:
total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 370.00
 $f_{fe} ((11-5), \text{ACI 440}) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 306911.784$
 $b_w \cdot d = \sqrt{2} \cdot d \cdot d / 4 = 80424.772$

End Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rccs

Constant Properties

Knowledge Factor, $\phi = 0.90$
Mean strength values are used for both shear and moment calculations.
Consequently:
New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

Diameter, $D = 400.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.56406

Element Length, L = 3000.00
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o/l_{ou}, \min \geq 1$)
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, t = 1.016
 Tensile Strength, f_{fu} = 1055.00
 Tensile Modulus, E_f = 64828.00
 Elongation, ϵ_{fu} = 0.01
 Number of directions, NoDir = 1
 Fiber orientations, b_i : 0.00°
 Number of layers, NL = 1
 Radius of rounding corners, R = 40.00

Stepwise Properties

At local axis: 2
 EDGE -A-
 Shear Force, V_a = -6.8378665E-048
 EDGE -B-
 Shear Force, V_b = 6.8378665E-048
 BOTH EDGES
 Axial Force, F = -4771.233
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: A_{st} = 0.00
 -Compression: A_{sc} = 3053.628
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{st,ten}$ = 1017.876
 -Compression: $A_{st,com}$ = 1017.876
 -Middle: $A_{st,mid}$ = 1017.876

Calculation of Shear Capacity ratio, V_e/V_r = 0.44725617
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 202038.041$
 with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 3.0306E+008$
 $\mu_{u1+} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u1-} = 3.0306E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 3.0306E+008$
 $\mu_{u2+} = 3.0306E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u2-} = 3.0306E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of μ_{u1+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ_u
 $\mu_u = 3.0306E+008$

= 1.02974
 ' = 0.91217079
 error of function (3.68), Biskinis Phd = 60360.02
 From 5A.2, TBDY: $f_{cc} = f_c^* \quad c = 51.61391$

conf. factor $c = 1.56406$
 $f_c = 33.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$
 $Ac = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/d

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

Calculation of μ_1 -

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 3.0306E+008$

$= 1.02974$
 $' = 0.91217079$
 error of function (3.68), Biskinis Phd = 60360.02
 From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 51.61391$
 conf. factor $c = 1.56406$
 $f_c = 33.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$
 $Ac = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$

Calculation of ratio l_b/d

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

Calculation of μ_2 +

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 3.0306E+008$

$= 1.02974$
 $' = 0.91217079$
 error of function (3.68), Biskinis Phd = 60360.02
 From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 51.61391$
 conf. factor $c = 1.56406$
 $f_c = 33.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$
 $l_b/d = 1.00$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00101663$
 $N = 4771.233$
 $Ac = 125663.706$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of μ_2

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 3.0306 \times 10^8$

$$= 1.02974$$

$$\lambda = 0.91217079$$

error of function (3.68), Biskinis Phd = 60360.02

From 5A.2, TB DY: $f_{cc} = f_c \cdot c = 51.61391$

conf. factor $c = 1.56406$

$f_c = 33.00$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 694.45$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00101663$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.45184585$$

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 451727.786$

Calculation of Shear Strength at edge 1, $V_{r1} = 451727.786$

$V_{r1} = V_{col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{col0}$

$$V_{col0} = 451727.786$$

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

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

$= 1$ (normal-weight concrete)

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

$$M/Vd = 2.00$$

$$\mu_u = 5.4715235 \times 10^{-12}$$

$$V_u = 6.8378665 \times 10^{-48}$$

$$d = 0.8 \cdot D = 320.00$$

$$N_u = 4771.233$$

$$A_g = 125663.706$$

From ((11.5.4.8), ACI 318-14: $V_s = 219326.297$

$$A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$$

$$f_y = 555.56$$

$$s = 100.00$$

V_s is multiplied by $\phi_{col} = 0.00$

$$s/d = 0.3125$$

V_f ((11-3)-(11.4), ACI 440) = 194961.134

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In ((11.3) $\sin + \cos$ is replaced with $(\cot + \cot_a) \sin a$ which is more a generalised expression,

where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 306911.784$

$b_w \cdot d = \rho \cdot d^2 / 4 = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 451727.786$

$V_{r2} = V_{\text{Col}}$ ((10.3), ASCE 41-17) = $k_n \cdot V_{\text{Col}0}$

$V_{\text{Col}0} = 451727.786$

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

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

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

$f'_c = 33.00$, but $f'_c \cdot 0.5 \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 5.4715235E-012$

$\nu_u = 6.8378665E-048$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 219326.297$

$A_v = \rho \cdot A_{\text{stirrup}} = 123370.055$

$f_y = 555.56$

$s = 100.00$

V_s is multiplied by $\rho_{\text{Col}} = 0.00$

$s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 194961.134

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 370.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 306911.784$

$b_w \cdot d = \rho \cdot d^2 / 4 = 80424.772$

End Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column CC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rccs

Constant Properties

Knowledge Factor, $\phi = 0.90$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/l_d \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 0.0481749$

Shear Force, $V_2 = 3007.62$

Shear Force, $V_3 = 1.5929820E-013$

Axial Force, $F = -4770.03$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{slt} = 0.00$

-Compression: $A_{slc} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1017.876$

-Compression: $A_{sl,com} = 1017.876$

-Middle: $A_{sl,mid} = 1017.876$

Mean Diameter of Tension Reinforcement, $D_bL = 18.00$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = 1.0^* u = 0.07452071$

$u = y + p = 0.07452071$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00297862 ((4.29), Biskinis Phd)$

$M_y = 3.0318E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.0179E+013$

factor = 0.30

$A_g = 125663.706$

$f_c' = 33.00$

$N = 4770.03$

$E_c * I_g = 3.3929E+013$

Calculation of Yielding Moment M_y

Calculation of γ and M_y according to (7) - (8) in Biskinis and Fardis

$M_y = \text{Min}(M_{y_ten}, M_{y_com}) = 3.0318\text{E}+008$
 $\gamma \text{ ((10a) or (10b))} = 1.6222681\text{E}-005$
 $M_{y_ten} \text{ (8a)} = 3.0318\text{E}+008$
 $\gamma_{ten} \text{ (7a)} = 69.35398$
 $\text{error of function (7a)} = 0.00743251$
 $M_{y_com} \text{ (8b)} = 4.6746\text{E}+008$
 $\gamma_{com} \text{ (7b)} = 67.1564$
 $\text{error of function (7b)} = -0.0026554$
with $e_y = 0.0027778$
 $e_{co} = 0.002$
 $a_{pl} = 0.45 \text{ ((9c) in Biskinis and Fardis for FRP Wrap)}$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00102233$
 $N = 4770.03$
 $A_c = 125663.706$
 $= 0.36359274$
with $f_c^* \text{ ((12.3), ACI 440)} = 37.12975$
 $f_c = 33.00$
 $f_l = 1.3173$
 $k = 1$
Effective FRP thickness, $t_f = N L^* t \cos(b_1) = 1.016$
 $e_{fe} \text{ ((12.5) and (12.7))} = 0.004$
 $E_f = 64828.00$

Calculation of ratio l_b/l_d

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

- Calculation of p -

From table 10-9: $p = 0.07154209$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$
shear control ratio $V_y E / V_{co} I_{OE} = 0.44725617$
 $d = 0.00$
 $s = 0.00$
 $t = 2 A_v / (d c^* s) + 4 t_f / D^* (f_{fe} / f_s) = 0.00$
 $A_v = 78.53982$, is the area of the circular stirrup
 $d c = D - 2^* \text{cover} - \text{Hoop Diameter} = 340.00$
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.
 $N U D = 4770.03$
 $A_g = 125663.706$
 $f_{cE} = 33.00$
 $f_{yE} = f_{yI} = 555.56$
 $p_l = \text{Area_Tot_Long_Rein} / (A_g) = 0.0243$
 $f_{cE} = 33.00$

End Of Calculation of Chord Rotation Capacity for element: column CC1 of floor 1

At local axis: 3

Integration Section: (b)