

Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

column C1, Floor 1

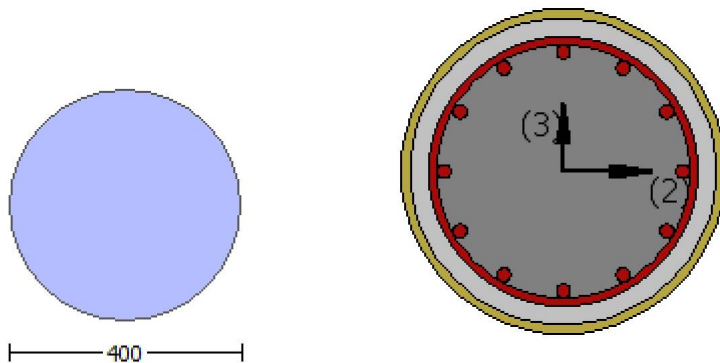
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity 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, $\gamma = 0.85$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of γ for displacement ductility demand,
 the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as
 Deformation-Controlled Action (Table C7-1, ASCE41-17).
 Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$
 #####
 Diameter, $D = 400.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou,min} = l_b/l_d = 0.30$
 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, $M_a = -8.3350E+006$
 Shear Force, $V_a = -2777.007$
 EDGE -B-
 Bending Moment, $M_b = 0.07583332$
 Shear Force, $V_b = 2777.007$
 BOTH EDGES
 Axial Force, $F = -4770.122$
 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, $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 224627.823$
 V_n ((10.3), ASCE 41-17) = $k_n l \cdot V_{CoIO} = 264268.027$
 $V_{CoI} = 264268.027$
 $k_n l = 1.00$
 $displacement_ductility_demand = 0.01625615$

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).

$\beta = 1$ (normal-weight concrete)
 $f'_c = 16.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 8.3350E+006$
 $V_u = 2777.007$
 $d = 0.8 \cdot D = 320.00$

$Nu = 4770.122$
 $Ag = 125663.706$
 From (11.5.4.8), ACI 318-14: $Vs = 157913.67$
 $Av = \frac{1}{2} * A_{stirrup} = 123370.055$
 $fy = 400.00$
 $s = 100.00$
 Vs is multiplied by $Col = 0.00$
 $s/d = 0.3125$
 Vf ((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 $Vf(\theta)$, 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: $\theta = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL * t / NoDir = 1.016$
 $dfv = d$ (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: $Vs + Vf \leq 213705.936$
 $bw * d = \frac{1}{4} * d * d = 80424.772$

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 $\theta = 0.00028185$
 $y = (My * Ls / 3) / Eleff = 0.01733836$ ((4.29), Biskinis Phd))
 $My = 1.3732E+008$
 $Ls = M/V$ (with $Ls > 0.1 * L$ and $Ls < 2 * L$) = 3001.447
 From table 10.5, ASCE 41_17: $Eleff = factor * Ec * Ig = 7.9240E+012$
 $factor = 0.30$
 $Ag = 125663.706$
 $fc' = 20.00$
 $N = 4770.122$
 $Ec * Ig = 2.6413E+013$

Calculation of Yielding Moment My

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

$My = \text{Min}(My_{ten}, My_{com}) = 1.3732E+008$
 $y = 7.5716684E-006$
 My_{ten} (8c) = 1.3732E+008
 δ_{ten} (7c) = 72.23345
 error of function (7c) = 0.00097594
 My_{com} (8d) = 3.7493E+008
 δ_{com} (7d) = 69.91126
 error of function (7d) = 0.00301333
 with ((10.1), ASCE 41-17) $ey = \text{Min}(ey, 1.25 * ey * (lb/d)^{2/3}) = 0.00222222$
 $eco = 0.002$
 $apl = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d1 = 44.00$
 $R = 200.00$
 $v = 0.00157314$
 $N = 4770.122$
 $Ac = 125663.706$
 ((10.1), ASCE 41-17) $\delta = \text{Min}(\delta, 1.25 * \delta * (lb/d)^{2/3}) = 0.44758025$

with f_c^* ((12.3), ACI 440) = 24.12975
 $f_c = 20.00$
 $f_l = 1.3173$
 $k = 1$
Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $f_u = 0.01$
 $E_f = 64828.00$

Calculation of ratio I_b/I_d

Inadequate Lap Length with $I_b/I_d = 0.30$

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

At local axis: 2

Integration Section: (a)

Calculation No. 2

column C1, Floor 1

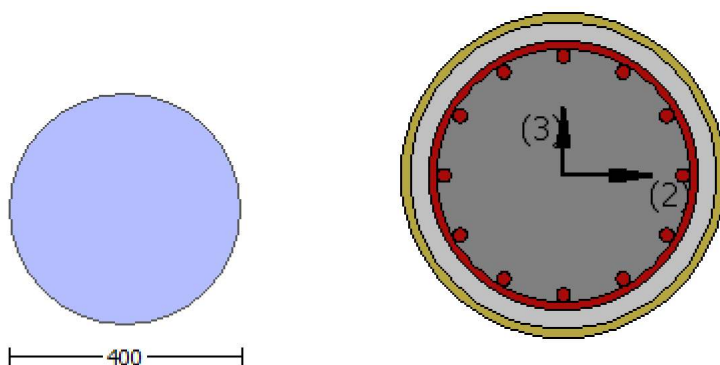
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

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, $\phi = 0.85$

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

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Note: Especially for the calculation of moment strengths,

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

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$

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Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.84055

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$

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, $ef_u = 0.01$

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: 3

EDGE -A-

Shear Force, $V_a = -3.7968243E-031$

EDGE -B-

Shear Force, $V_b = 3.7968243E-031$

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, $V_e/V_r = 0.27402927$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96425.251$

with

$M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 1.4464E+008$

$\mu_{u1+} = 1.4464E+008$, 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

$\mu_{u1-} = 1.4464E+008$, 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

$M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 1.4464E+008$

$\mu_{u2+} = 1.4464E+008$, 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

$\mu_{u2-} = 1.4464E+008$, 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 Mu1+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

= 0.9250245
' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 36.81095$
conf. factor $c = 1.84055$
 $f_c = 20.00$
From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $Ac = 125663.706$
= $\cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

= 0.9250245
' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 36.81095$
conf. factor $c = 1.84055$
 $f_c = 20.00$
From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $Ac = 125663.706$
= $\cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

$\lambda = 0.9250245$
 $\lambda' = 0.82105152$
 error of function (3.68), Biskinis Phd = 31682.903
 From 5A.2, TDY: $f_{cc} = f_c' \cdot c = 36.81095$
 conf. factor $c = 1.84055$
 $f_c = 20.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $\lambda = \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_2 -

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 1.4464\text{E}+008$

$\lambda = 0.9250245$
 $\lambda' = 0.82105152$
 error of function (3.68), Biskinis Phd = 31682.903
 From 5A.2, TDY: $f_{cc} = f_c' \cdot c = 36.81095$
 conf. factor $c = 1.84055$
 $f_c = 20.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $\lambda = \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 351879.387$

Calculation of Shear Strength at edge 1, $V_{r1} = 351879.387$

$V_{r1} = V_{c0} \text{ ((10.3), ASCE 41-17)} = k_n \cdot V_{c0}$

$V_{c0} = 351879.387$

$k_n = 1$ (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).

$\lambda = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/d = 2.00$
 $\mu = 9.8466009\text{E}-012$
 $V_u = 3.7968243\text{E}-031$

$d = 0.8 \cdot D = 320.00$
 $Nu = 4771.233$
 $Ag = 125663.706$
 From (11.5.4.8), ACI 318-14: $Vs = 175459.634$
 $Av = \frac{1}{2} \cdot A_{stirrup} = 123370.055$
 $fy = 444.4444$
 $s = 100.00$
 Vs is multiplied by $Col = 0.00$
 $s/d = 0.3125$
 Vf ((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 $Vf(,)$, 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: $\theta_1 = b_1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, \theta_1)|, |Vf(-45, a_1)|)$, with:
 total thickness per orientation, $tf_1 = NL \cdot t / NoDir = 1.016$
 $dfv = d$ (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: $Vs + Vf \leq 238930.50$
 $bw \cdot d = \frac{1}{4} \cdot d^2 = 80424.772$

Calculation of Shear Strength at edge 2, $Vr2 = 351879.387$
 $Vr2 = VCol$ ((10.3), ASCE 41-17) = $knl \cdot VColO$
 $VColO = 351879.387$
 $knl = 1$ (zero step-static loading)

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

$\beta = 1$ (normal-weight concrete)
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $Mu = 9.8466009E-012$
 $Vu = 3.7968243E-031$
 $d = 0.8 \cdot D = 320.00$
 $Nu = 4771.233$
 $Ag = 125663.706$
 From (11.5.4.8), ACI 318-14: $Vs = 175459.634$
 $Av = \frac{1}{2} \cdot A_{stirrup} = 123370.055$
 $fy = 444.4444$
 $s = 100.00$
 Vs is multiplied by $Col = 0.00$
 $s/d = 0.3125$
 Vf ((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 $Vf(,)$, 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: $\theta_1 = b_1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, \theta_1)|, |Vf(-45, a_1)|)$, with:
 total thickness per orientation, $tf_1 = NL \cdot t / NoDir = 1.016$
 $dfv = d$ (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: $Vs + Vf \leq 238930.50$
 $bw \cdot d = \frac{1}{4} \cdot d^2 = 80424.772$

End Of Calculation of Shear Capacity ratio for element: column CC1 of floor 1
At local axis: 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, $\gamma = 0.85$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$

Diameter, $D = 400.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.84055
Element Length, $L = 3000.00$
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
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, $V_a = 4.4296389E-033$
EDGE -B-
Shear Force, $V_b = -4.4296389E-033$
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 , $V_e/V_r = 0.27402927$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96425.251$
with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.4464E+008$

$M_{u1+} = 1.4464E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 1.4464E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.4464E+008$

$M_{u2+} = 1.4464E+008$, 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

$M_{u2-} = 1.4464E+008$, 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
 $M_u = 1.4464E+008$

$\phi = 0.9250245$

$\phi' = 0.82105152$

error of function (3.68), Biskinis Phd = 31682.903

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 36.81095$

conf. factor $c = 1.84055$

$f_c = 20.00$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 311.2087$

$l_b/l_d = 0.30$

$d_1 = 44.00$

$R = 200.00$

$v = 0.00155946$

$N = 4771.233$

$A_c = 125663.706$

$= \phi' \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u1-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), M_u
 $M_u = 1.4464E+008$

$\phi = 0.9250245$

$\phi' = 0.82105152$

error of function (3.68), Biskinis Phd = 31682.903

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 36.81095$

conf. factor $c = 1.84055$

$f_c = 20.00$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 311.2087$

$l_b/l_d = 0.30$

$d_1 = 44.00$

$R = 200.00$

$v = 0.00155946$

$N = 4771.233$

$$A_c = 125663.706$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_{2+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 1.4464\text{E}+008$

$$= 0.9250245$$

$$\lambda = 0.82105152$$

error of function (3.68), Biskinis Phd = 31682.903

From 5A.2, TDY: $f_{cc} = f_c \cdot c = 36.81095$

conf. factor $c = 1.84055$

$f_c = 20.00$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$

$l_b/d = 0.30$

$d_1 = 44.00$

$R = 200.00$

$v = 0.00155946$

$N = 4771.233$

$A_c = 125663.706$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_{2-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 1.4464\text{E}+008$

$$= 0.9250245$$

$$\lambda = 0.82105152$$

error of function (3.68), Biskinis Phd = 31682.903

From 5A.2, TDY: $f_{cc} = f_c \cdot c = 36.81095$

conf. factor $c = 1.84055$

$f_c = 20.00$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$

$l_b/d = 0.30$

$d_1 = 44.00$

$R = 200.00$

$v = 0.00155946$

$N = 4771.233$

$A_c = 125663.706$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 351879.387$

Calculation of Shear Strength at edge 1, $V_{r1} = 351879.387$

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

$V_{Col0} = 351879.387$

$k_{nl} = 1$ (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).

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

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

$M / Vd = 2.00$

$\mu_u = 9.0356326E-012$

$\nu_u = 4.4296389E-033$

$d = 0.8 * D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 175459.634$

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

$f_y = 444.4444$

$s = 100.00$

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 $V_f(\theta)$, 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: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \min(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:

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

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 238930.50$

$b_w * d = \frac{1}{4} * d^2 = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 351879.387$

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

$V_{Col0} = 351879.387$

$k_{nl} = 1$ (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).

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

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

$M / Vd = 2.00$

$\mu_u = 9.0356326E-012$

$\nu_u = 4.4296389E-033$

$d = 0.8 * D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 175459.634$

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

$f_y = 444.4444$

$s = 100.00$

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 $V_f(,)$, 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: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, 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: $V_s + V_f \leq 238930.50$

$b_w \cdot d = \cdot d \cdot d / 4 = 80424.772$

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: 2
Integration Section: (a)
Section Type: rccs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_b/l_d = 0.30$

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, $M = 2.7525396\text{E-}011$

Shear Force, $V_2 = -2777.007$

Shear Force, $V_3 = -1.4226804\text{E-}014$

Axial Force, $F = -4770.122$
 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, $Db_L = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = u = 0.00736525$
 $u = y + p = 0.008665$

- Calculation of y -

$y = (My * L_s / 3) / E_{eff} = 0.008665$ ((4.29), Biskinis Phd))
 $My = 1.3732E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 7.9240E+012$
 $factor = 0.30$
 $A_g = 125663.706$
 $f_c' = 20.00$
 $N = 4770.122$
 $E_c * I_g = 2.6413E+013$

Calculation of Yielding Moment My

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

$My = \min(My_{ten}, My_{com}) = 1.3732E+008$
 $y = 7.5716684E-006$
 $My_{ten} (8c) = 1.3732E+008$
 $_{ten} (7c) = 72.23345$
 $error\ of\ function\ (7c) = 0.00097594$
 $My_{com} (8d) = 3.7493E+008$
 $_{com} (7d) = 69.91126$
 $error\ of\ function\ (7d) = 0.00301333$
 with ((10.1), ASCE 41-17) $ey = \min(ey, 1.25 * ey * (I_b / I_d)^{2/3}) = 0.00222222$
 $eco = 0.002$
 $apl = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d1 = 44.00$
 $R = 200.00$
 $v = 0.00157314$
 $N = 4770.122$
 $A_c = 125663.706$
 ((10.1), ASCE 41-17) $= \min(, 1.25 * (I_b / I_d)^{2/3}) = 0.44758025$
 with $f_c' ((12.3), ACI 440) = 24.12975$
 $f_c = 20.00$
 $f_l = 1.3173$
 $k = 1$
 Effective FRP thickness, $t_f = NL * t * \cos(b1) = 1.016$
 $efe ((12.5) \text{ and } (12.7)) = 0.004$
 $fu = 0.01$
 $E_f = 64828.00$

Calculation of ratio I_b / I_d

Inadequate Lap Length with $I_b / I_d = 0.30$

- Calculation of p -

From table 10-9: $p = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
shear control ratio $V_{yE}/V_{CoIE} = 0.27402927$

$d = 0.00$

$s = 0.00$

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

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

$d_c = D - 2 \cdot \text{cover}$ - 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.

$NUD = 4770.122$

$Ag = 125663.706$

$f_{cE} = 20.00$

$f_{yE} = f_{yIE} = 444.4444$

$p_l = \text{Area_Tot_Long_Rein} / (Ag) = 0.0243$

$f_{cE} = 20.00$

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

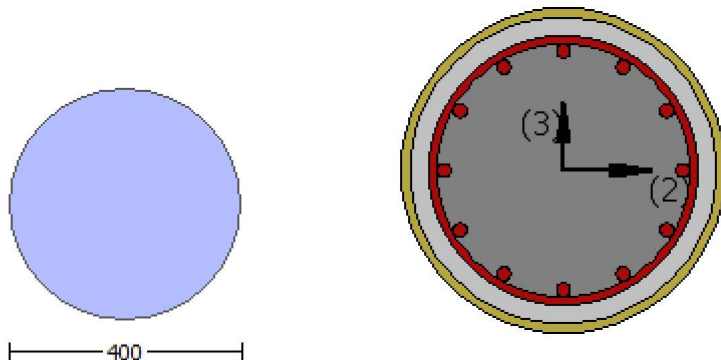
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

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, $\phi = 0.85$
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of γ for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE41-17).
Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$

Diameter, $D = 400.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_o/l_{ou,min} = l_b/l_d = 0.30$
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, $N_{oDir} = 1$
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, $M_a = 2.7525396E-011$
Shear Force, $V_a = -1.4226804E-014$
EDGE -B-
Bending Moment, $M_b = 1.5086324E-011$
Shear Force, $V_b = 1.4226804E-014$
BOTH EDGES
Axial Force, $F = -4770.122$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 1272.345$
-Compression: $A_{sc} = 1781.283$
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, $D_{bL,ten} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 267605.60$
 V_n ((10.3), ASCE 41-17) = $k_n \phi V_{Co10} = 314830.118$

VCol = 314830.118
 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)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 2.7525396E-011$
 $V_u = 1.4226804E-014$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4770.122$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 157913.67$
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 400.00$
 $s = 100.00$
 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 $(\cot + \cot \alpha) \sin \alpha$ 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, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (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: $V_s + V_f \leq 213705.936$
 $b_w \cdot d = \sqrt{V_s + V_f} \cdot d / 4 = 80424.772$

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 $\theta = 4.7943297E-021$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.008665$ ((4.29), Biskinis Phd))
 $M_y = 1.3732E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 7.9240E+012$
 factor = 0.30
 $A_g = 125663.706$
 $f_c' = 20.00$
 $N = 4770.122$
 $E_c \cdot I_g = 2.6413E+013$

Calculation of Yielding Moment M_y

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

$M_y = \text{Min}(M_{y_ten}, M_{y_com}) = 1.3732E+008$
 $\delta = 7.5716684E-006$
 M_{y_ten} (8c) = 1.3732E+008
 δ_{ten} (7c) = 72.23345

error of function (7c) = 0.00097594
 My_com (8d) = 3.7493E+008
 _com (7d) = 69.91126
 error of function (7d) = 0.00301333
 with ((10.1), ASCE 41-17) ey = Min(ey, $1.25 \cdot e_y \cdot (l_b/l_d)^{2/3}$) = 0.00222222
 eco = 0.002
 apl = 0.45 ((9c) in Biskinis and Fardis for FRP Wrap)
 d1 = 44.00
 R = 200.00
 v = 0.00157314
 N = 4770.122
 Ac = 125663.706
 ((10.1), ASCE 41-17) = Min(, $1.25 \cdot \cdot (l_b/l_d)^{2/3}$) = 0.44758025
 with fc* ((12.3), ACI 440) = 24.12975
 fc = 20.00
 fl = 1.3173
 k = 1
 Effective FRP thickness, tf = $NL \cdot t \cdot \cos(b1)$ = 1.016
 efe ((12.5) and (12.7)) = 0.004
 fu = 0.01
 Ef = 64828.00

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

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

At local axis: 3

Integration Section: (a)

Calculation No. 4

column C1, Floor 1

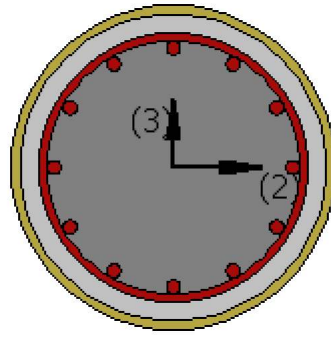
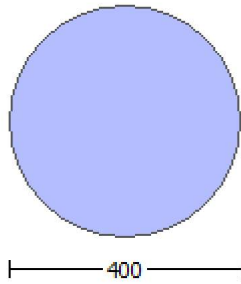
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

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, $\gamma = 0.85$

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.84055

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$

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, $V_a = -3.7968243E-031$

EDGE -B-

Shear Force, $V_b = 3.7968243E-031$

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: $A_{sl,mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.27402927$
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96425.251$
 with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.4464E+008$
 $M_{u1+} = 1.4464E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $M_{u1-} = 1.4464E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.4464E+008$
 $M_{u2+} = 1.4464E+008$, 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
 $M_{u2-} = 1.4464E+008$, 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
 $M_u = 1.4464E+008$

$\phi = 0.9250245$
 $\lambda = 0.82105152$
 error of function (3.68), Biskinis Phd = 31682.903
 From 5A.2, TDY: $f_{cc} = f_c \cdot c = 36.81095$
 conf. factor $c = 1.84055$
 $f_c = 20.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $\phi \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of M_{u1-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), M_u
 $M_u = 1.4464E+008$

$\phi = 0.9250245$
 $\lambda = 0.82105152$
 error of function (3.68), Biskinis Phd = 31682.903
 From 5A.2, TDY: $f_{cc} = f_c \cdot c = 36.81095$
 conf. factor $c = 1.84055$

$f_c = 20.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_{2+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 1.4464E+008$

$= 0.9250245$
 $' = 0.82105152$
 error of function (3.68), Biskinis Phd = 31682.903
 From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 36.81095$
 conf. factor $c = 1.84055$
 $f_c = 20.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_{2-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 1.4464E+008$

$= 0.9250245$
 $' = 0.82105152$
 error of function (3.68), Biskinis Phd = 31682.903
 From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 36.81095$
 conf. factor $c = 1.84055$
 $f_c = 20.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 351879.387$

Calculation of Shear Strength at edge 1, $V_{r1} = 351879.387$

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

$V_{Col0} = 351879.387$

$k_n l = 1$ (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).

$= 1$ (normal-weight concrete)

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

$M/Vd = 2.00$

$M_u = 9.8466009E-012$

$V_u = 3.7968243E-031$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 175459.634$

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

$f_y = 444.4444$

$s = 100.00$

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

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, 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: $V_s + V_f \leq 238930.50$

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

Calculation of Shear Strength at edge 2, $V_{r2} = 351879.387$

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

$V_{Col0} = 351879.387$

$k_n l = 1$ (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).

$= 1$ (normal-weight concrete)

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

$M/Vd = 2.00$

$M_u = 9.8466009E-012$

$V_u = 3.7968243E-031$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 175459.634$
 $A_v = \frac{1}{2} A_{stirrup} = 123370.055$
 $f_y = 444.4444$
 $s = 100.00$
 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 $V_f(\theta, a)$, 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: $V_s + V_f \leq 238930.50$
 $b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 80424.772$

 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, $\phi = 0.85$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$
 #####
 Diameter, $D = 400.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.84055
 Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou, \min} = 0.30$
 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, $bi: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 4.4296389E-033$
EDGE -B-
Shear Force, $V_b = -4.4296389E-033$
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, $V_e/V_r = 0.27402927$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96425.251$
with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 1.4464E+008$
 $\mu_{u1+} = 1.4464E+008$, 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
 $\mu_{u1-} = 1.4464E+008$, 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
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 1.4464E+008$
 $\mu_{u2+} = 1.4464E+008$, 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
 $\mu_{u2-} = 1.4464E+008$, 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
 $\mu_u = 1.4464E+008$

$= 0.9250245$
 $' = 0.82105152$
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: $f_{cc} = f_c^* \quad c = 36.81095$
conf. factor $c = 1.84055$
 $f_c = 20.00$
From 10.3.5, ASCE41-17, Final value of $f_y: f_y \cdot \min(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \min(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{1-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 1.4464E+008$

$$= 0.9250245$$

$$' = 0.82105152$$

error of function (3.68), Biskinis Phd = 31682.903

From 5A.2, TDY: $f_{cc} = f_c \cdot c = 36.81095$

conf. factor $c = 1.84055$

$$f_c = 20.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 311.2087$

$$l_b/l_d = 0.30$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00155946$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.31060654$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{2+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 1.4464E+008$

$$= 0.9250245$$

$$' = 0.82105152$$

error of function (3.68), Biskinis Phd = 31682.903

From 5A.2, TDY: $f_{cc} = f_c \cdot c = 36.81095$

conf. factor $c = 1.84055$

$$f_c = 20.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 311.2087$

$$l_b/l_d = 0.30$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00155946$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.31060654$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{2-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), M_u
 $M_u = 1.4464E+008$

$\phi = 0.9250245$
 $\phi' = 0.82105152$
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: $f_{cc} = f_c' \cdot c = 36.81095$
conf. factor $c = 1.84055$
 $f_c = 20.00$
From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 311.2087$
 $l_b/l_d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \phi' \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 351879.387$

Calculation of Shear Strength at edge 1, $V_{r1} = 351879.387$
 $V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 351879.387$
 $k_{nl} = 1$ (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).

$\phi = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa ((22.5.3.1, ACI 318-14))
 $M/Vd = 2.00$
 $M_u = 9.0356326E-012$
 $V_u = 4.4296389E-033$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
From ((11.5.4.8), ACI 318-14: $V_s = 175459.634$
 $A_v = \phi' / 2 \cdot A_{stirrup} = 123370.055$
 $f_y = 444.4444$
 $s = 100.00$
 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: $\theta_1 = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \alpha_1)|)$, 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), 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: $V_s + V_f \leq 238930.50$
 $b_w \cdot d = \phi' \cdot d^2 / 4 = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 351879.387$

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

$V_{Col0} = 351879.387$

$knl = 1$ (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)

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

$M/Vd = 2.00$

$\mu_u = 9.0356326E-012$

$\nu_u = 4.4296389E-033$

$d = 0.8 * D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 175459.634$

$A_v = /2 * A_{stirrup} = 123370.055$

$f_y = 444.4444$

$s = 100.00$

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, $= 45^\circ$ 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, $t_{f1} = NL * t / NoDir = 1.016$

$d_{fv} = d$ (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: $V_s + V_f \leq 238930.50$

$bw * d = * d * d / 4 = 80424.772$

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: 3

Integration Section: (a)

Section Type: rccs

Constant Properties

Knowledge Factor, $= 0.85$

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

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_b/l_d = 0.30$
 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, $M = -8.3350E+006$
 Shear Force, $V_2 = -2777.007$
 Shear Force, $V_3 = -1.4226804E-014$
 Axial Force, $F = -4770.122$
 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, $Db_L = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{R} = u = 0.01473761$
 $u = y + p = 0.01733836$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.01733836$ ((4.29), Biskinis Phd))
 $M_y = 1.3732E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3001.447
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 7.9240E+012$
 factor = 0.30
 $A_g = 125663.706$
 $f_c' = 20.00$
 $N = 4770.122$
 $E_c * I_g = 2.6413E+013$

Calculation of Yielding Moment M_y

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

$M_y = \min(M_{y_ten}, M_{y_com}) = 1.3732E+008$
 $y = 7.5716684E-006$
 $M_{y_ten} (8c) = 1.3732E+008$
 $_{ten} (7c) = 72.23345$
 error of function (7c) = 0.00097594
 $M_{y_com} (8d) = 3.7493E+008$
 $_{com} (7d) = 69.91126$
 error of function (7d) = 0.00301333

with ((10.1), ASCE 41-17) $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.00222222$
 $e_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00157314$
 $N = 4770.122$
 $A_c = 125663.706$
 ((10.1), ASCE 41-17) $= \text{Min}(, 1.25 * (l_b / l_d)^{2/3}) = 0.44758025$
 with f_c^* ((12.3), ACI 440) = 24.12975
 $f_c = 20.00$
 $f_l = 1.3173$
 $k = 1$
 Effective FRP thickness, $t_f = N L * t * \cos(b_1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $f_u = 0.01$
 $E_f = 64828.00$

Calculation of ratio l_b / l_d

Inadequate Lap Length with $l_b / l_d = 0.30$

- Calculation of p -

From table 10-9: $p = 0.00$

with:

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

shear control ratio $V_y E / V_{colOE} = 0.27402927$

$d = 0.00$

$s = 0.00$

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

$A_v = 78.53982$, 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.

$N_{UD} = 4770.122$

$A_g = 125663.706$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 444.4444$

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

$f_{cE} = 20.00$

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

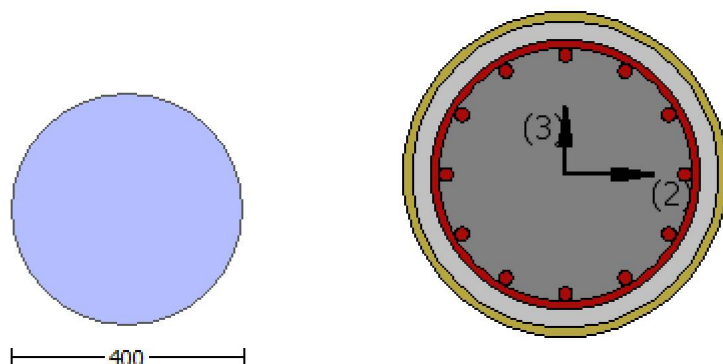
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

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, $\gamma = 0.85$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

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, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

EDGE -A-
Bending Moment, Ma = -8.3350E+006
Shear Force, Va = -2777.007
EDGE -B-
Bending Moment, Mb = 0.07583332
Shear Force, Vb = 2777.007
BOTH EDGES
Axial Force, F = -4770.122
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 3053.628
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,ten = 18.00

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity VR = *Vn = 267605.60
Vn ((10.3), ASCE 41-17) = knl*VCol0 = 314830.118
VCol = 314830.118
knl = 1.00
displacement_ductility_demand = 0.09103583

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).

= 1 (normal-weight concrete)
fc' = 16.00, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
M/Vd = 2.00
Mu = 0.07583332
Vu = 2777.007
d = 0.8*D = 320.00
Nu = 4770.122
Ag = 125663.706
From (11.5.4.8), ACI 318-14: Vs = 157913.67
Av = /2*A_stirrup = 123370.055
fy = 400.00
s = 100.00
Vs is multiplied by Col = 0.00
s/d = 0.3125
Vf ((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 is the angle of the crack direction (see KANEPE).
This later relation, considered as a function Vf(,), is implemented for every different fiber orientation ai,
as well as for 2 crack directions, =45° and =-45° to take into consideration the cyclic seismic loading.
orientation 1: 1 = b1 + 90° = 90.00
Vf = Min(|Vf(45, 1)|, |Vf(-45,a1)|), with:
total thickness per orientation, tf1 = NL*t/NoDir = 1.016
dfv = 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 <= 213705.936
bw*d = *d*d/4 = 80424.772

displacement_ductility_demand is calculated as ϕ / y

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

From analysis, chord rotation $\theta = 0.00015777$
 $y = (M_y * L_s / 3) / E_{eff} = 0.001733$ ((4.29), Biskinis Phd))
 $M_y = 1.3732E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 7.9240E+012$
factor = 0.30
Ag = 125663.706
fc' = 20.00
N = 4770.122
 $E_c * I_g = 2.6413E+013$

Calculation of Yielding Moment M_y

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

$M_y = \min(M_{y_ten}, M_{y_com}) = 1.3732E+008$
 $y = 7.5716684E-006$
 $M_{y_ten} (8c) = 1.3732E+008$
 $\phi_{ten} (7c) = 72.23345$
error of function (7c) = 0.00097594
 $M_{y_com} (8d) = 3.7493E+008$
 $\phi_{com} (7d) = 69.91126$
error of function (7d) = 0.00301333
with ((10.1), ASCE 41-17) $e_y = \min(e_y, 1.25 * e_y * (I_b / I_d)^{2/3}) = 0.00222222$
eco = 0.002
apl = 0.45 ((9c) in Biskinis and Fardis for FRP Wrap)
d1 = 44.00
R = 200.00
v = 0.00157314
N = 4770.122
Ac = 125663.706
((10.1), ASCE 41-17) $\phi = \min(\phi, 1.25 * \phi * (I_b / I_d)^{2/3}) = 0.44758025$
with fc' ((12.3), ACI 440) = 24.12975
fc = 20.00
fl = 1.3173
k = 1
Effective FRP thickness, tf = NL * t * Cos(b1) = 1.016
efe ((12.5) and (12.7)) = 0.004
fu = 0.01
Ef = 64828.00

Calculation of ratio I_b / I_d

Inadequate Lap Length with $I_b / I_d = 0.30$

End Of Calculation of Shear Capacity for element: column CC1 of floor 1
At local axis: 2
Integration Section: (b)

Calculation No. 6

column C1, Floor 1

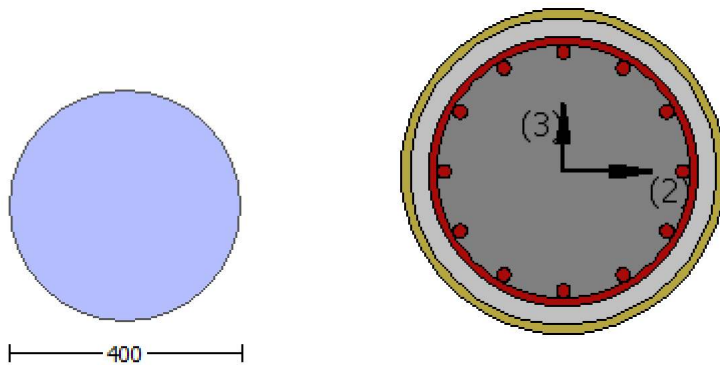
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

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, $\gamma = 0.85$

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.84055

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$

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: 3
EDGE -A-
Shear Force, $V_a = -3.7968243E-031$
EDGE -B-
Shear Force, $V_b = 3.7968243E-031$
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: $As_{l,ten} = 1017.876$
-Compression: $As_{l,com} = 1017.876$
-Middle: $As_{l,mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.27402927$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96425.251$
with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 1.4464E+008$
 $\mu_{u1+} = 1.4464E+008$, 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
 $\mu_{u1-} = 1.4464E+008$, 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
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 1.4464E+008$
 $\mu_{u2+} = 1.4464E+008$, 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
 $\mu_{u2-} = 1.4464E+008$, 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
 $\mu_u = 1.4464E+008$

$\phi = 0.9250245$
 $\phi' = 0.82105152$
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: $f_{cc} = f_c^* \quad c = 36.81095$
conf. factor $c = 1.84055$
 $f_c = 20.00$
From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \min(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $\phi' = \phi \cdot \min(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_{u1} -

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ_u
 $\mu_u = 1.4464E+008$

$$= 0.9250245$$

$$' = 0.82105152$$

error of function (3.68), Biskinis Phd = 31682.903

From 5A.2, TDY: $f_{cc} = f_c \cdot c = 36.81095$

conf. factor $c = 1.84055$

$$f_c = 20.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$

$$l_b/d = 0.30$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00155946$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_{u2+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ_u
 $\mu_u = 1.4464E+008$

$$= 0.9250245$$

$$' = 0.82105152$$

error of function (3.68), Biskinis Phd = 31682.903

From 5A.2, TDY: $f_{cc} = f_c \cdot c = 36.81095$

conf. factor $c = 1.84055$

$$f_c = 20.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$

$$l_b/d = 0.30$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00155946$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_{u2-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 1.4464E+008$

$\lambda = 0.9250245$
 $\lambda' = 0.82105152$
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: $f_{cc} = f_c' \cdot \lambda = 36.81095$
conf. factor $\lambda = 1.84055$
 $f_c = 20.00$
From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \lambda' \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 351879.387$

Calculation of Shear Strength at edge 1, $V_{r1} = 351879.387$

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

$V_{ColO} = 351879.387$

$k_{nl} = 1$ (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)

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

$M/Vd = 2.00$

$\mu = 9.8466009E-012$

$\nu = 3.7968243E-031$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 175459.634$

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

$f_y = 444.4444$

$s = 100.00$

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

$s/d = 0.3125$

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

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \alpha_1)|)$, 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: $V_s + V_f \leq 238930.50$
 $b_w d = \frac{A_s f_y}{4} = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 351879.387$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l V_{Col0}$
 $V_{Col0} = 351879.387$
 $k_n l = 1$ (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).

$\lambda = 1$ (normal-weight concrete)
 $f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa ((22.5.3.1), ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 9.8466009E-012$
 $\nu_u = 3.7968243E-031$
 $d = 0.8D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
From ((11.5.4.8), ACI 318-14: $V_s = 175459.634$
 $A_v = \frac{1}{2} A_{stirrup} = 123370.055$
 $f_y = 444.4444$
 $s = 100.00$
 V_s is multiplied by $\lambda = 1.00$
 $s/d = 0.3125$
 V_f ((11-3)-(11.4), ACI 440) = 194961.134
 $f = 0.95$, 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: $\alpha_1 = \alpha_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, \alpha_1)|)$, with:
total thickness per orientation, $t_{f1} = N_L t / N_{Dir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 370.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_{fe} = 0.004$, from ((11.6a), ACI 440)
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 238930.50$
 $b_w d = \frac{A_s f_y}{4} = 80424.772$

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, $\lambda = 0.85$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$
#####

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

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.84055

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$

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, $V_a = 4.4296389E-033$

EDGE -B-

Shear Force, $V_b = -4.4296389E-033$

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 , $V_e/V_r = 0.27402927$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96425.251$

with

$M_{pr1} = \text{Max}(\mu_{u1+} , \mu_{u1-}) = 1.4464E+008$

$\mu_{u1+} = 1.4464E+008$, 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

$\mu_{u1-} = 1.4464E+008$, 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

$M_{pr2} = \text{Max}(\mu_{u2+} , \mu_{u2-}) = 1.4464E+008$

$\mu_{u2+} = 1.4464E+008$, 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

$\mu_{u2-} = 1.4464E+008$, 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 = 1.4464E+008

= 0.9250245
' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: $f_{cc} = f_c^* \quad c = 36.81095$
conf. factor $c = 1.84055$
 $f_c = 20.00$
From 10.3.5, ASCE41-17, Final value of f_y : $f_y * \text{Min}(1, 1.25 * (l_b / l_d)^{2/3}) = 311.2087$
 $l_b / l_d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $= * \text{Min}(1, 1.25 * (l_b / l_d)^{2/3}) = 0.31060654$

Calculation of ratio l_b / l_d

Inadequate Lap Length with $l_b / l_d = 0.30$

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

= 0.9250245
' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: $f_{cc} = f_c^* \quad c = 36.81095$
conf. factor $c = 1.84055$
 $f_c = 20.00$
From 10.3.5, ASCE41-17, Final value of f_y : $f_y * \text{Min}(1, 1.25 * (l_b / l_d)^{2/3}) = 311.2087$
 $l_b / l_d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $= * \text{Min}(1, 1.25 * (l_b / l_d)^{2/3}) = 0.31060654$

Calculation of ratio l_b / l_d

Inadequate Lap Length with $l_b / l_d = 0.30$

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

= 0.9250245
' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: $f_{cc} = f_c^* \quad c = 36.81095$
conf. factor $c = 1.84055$
 $f_c = 20.00$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$

$$l_b/d = 0.30$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00155946$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_2 -

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

$$\mu = 1.4464 \times 10^8$$

$$= 0.9250245$$

$$\cdot = 0.82105152$$

error of function (3.68), Biskinis Phd = 31682.903

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 36.81095$

$$\text{conf. factor } c = 1.84055$$

$$f_c = 20.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$

$$l_b/d = 0.30$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00155946$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 351879.387$

Calculation of Shear Strength at edge 1, $V_{r1} = 351879.387$

$$V_{r1} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = k_n l \cdot V_{CoI0}$$

$$V_{CoI0} = 351879.387$$

$$k_n l = 1 \text{ (zero step-static loading)}$$

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).

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

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

$$M/Vd = 2.00$$

$$\mu = 9.0356326 \times 10^{-12}$$

$$V_u = 4.4296389 \times 10^{-33}$$

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

$$N_u = 4771.233$$

$$A_g = 125663.706$$

From (11.5.4.8), ACI 318-14: $V_s = 175459.634$

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

$$f_y = 444.4444$$

$s = 100.00$
 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 $V_f(,)$, 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, $tf_1 = NL * t / NoDir = 1.016$
 $df_v = d$ (figure 11.2, ACI 440) = 370.00
 $ffe ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
with $fu = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 238930.50$
 $bw * d = s * d * d / 4 = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 351879.387$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{ColO}$
 $V_{ColO} = 351879.387$
 $knl = 1$ (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).

$\lambda = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 9.0356326E-012$
 $\mu_v = 4.4296389E-033$
 $d = 0.8 * D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
From (11.5.4.8), ACI 318-14: $V_s = 175459.634$
 $A_v = \lambda / 2 * A_{stirrup} = 123370.055$
 $f_y = 444.4444$
 $s = 100.00$
 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 $V_f(,)$, 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, $tf_1 = NL * t / NoDir = 1.016$
 $df_v = d$ (figure 11.2, ACI 440) = 370.00
 $ffe ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
with $fu = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 238930.50$
 $bw * d = s * d * d / 4 = 80424.772$

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: (b)

Section Type: rccs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_b/l_d = 0.30$

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, $M = 1.5086324E-011$

Shear Force, $V_2 = 2777.007$

Shear Force, $V_3 = 1.4226804E-014$

Axial Force, $F = -4770.122$

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, $Db_L = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \gamma \cdot u = 0.00736525$

$u = \gamma \cdot u + p = 0.008665$

- Calculation of γ -

$\gamma = (M \cdot L_s / 3) / E_{eff} = 0.008665 ((4.29), \text{Biskinis Phd})$

$M \gamma = 1.3732E+008$

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

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 7.9240E+012$

factor = 0.30
 $A_g = 125663.706$
 $f_c' = 20.00$
 $N = 4770.122$
 $E_c I_g = 2.6413E+013$

Calculation of Yielding Moment M_y

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

$M_y = \min(M_{y_ten}, M_{y_com}) = 1.3732E+008$
 $\gamma = 7.5716684E-006$
 $M_{y_ten} (8c) = 1.3732E+008$
 $\gamma_{ten} (7c) = 72.23345$
error of function (7c) = 0.00097594
 $M_{y_com} (8d) = 3.7493E+008$
 $\gamma_{com} (7d) = 69.91126$
error of function (7d) = 0.00301333
with ((10.1), ASCE 41-17) $\gamma_y = \min(\gamma_y, 1.25 \cdot \gamma_y \cdot (I_b/I_d)^{2/3}) = 0.00222222$
 $\epsilon_{co} = 0.002$
 $\alpha_l = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00157314$
 $N = 4770.122$
 $A_c = 125663.706$
((10.1), ASCE 41-17) $\gamma = \min(\gamma, 1.25 \cdot \gamma \cdot (I_b/I_d)^{2/3}) = 0.44758025$
with $f_c' ((12.3), ACI 440) = 24.12975$
 $f_c = 20.00$
 $f_l = 1.3173$
 $k = 1$
Effective FRP thickness, $t_f = N L \cdot t \cdot \cos(b_1) = 1.016$
 $\epsilon_{fe} ((12.5) \text{ and } (12.7)) = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$

Calculation of ratio I_b/I_d

Inadequate Lap Length with $I_b/I_d = 0.30$

- Calculation of p -

From table 10-9: $p = 0.00$

with:

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

shear control ratio $V_y E / V_{col} O E = 0.27402927$

$d = 0.00$

$s = 0.00$

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

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

$d_c = D - 2 \cdot \text{cover}$ - 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.

$N_{UD} = 4770.122$

$A_g = 125663.706$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 444.4444$

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

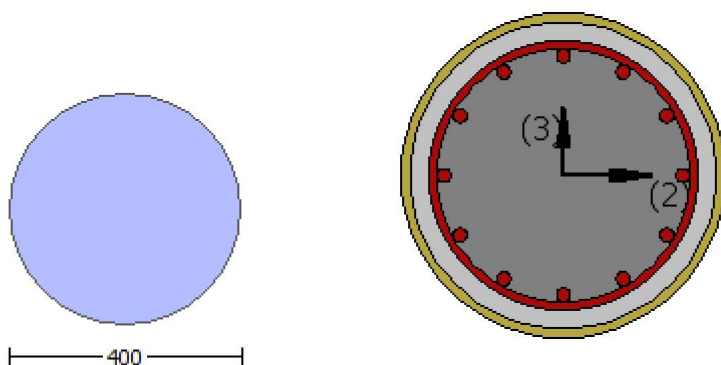
$f_{cE} = 20.00$

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 VR_d
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, $\gamma = 0.85$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou,min} = l_b/l_d = 0.30$
 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, $M_a = 2.7525396E-011$
 Shear Force, $V_a = -1.4226804E-014$
 EDGE -B-
 Bending Moment, $M_b = 1.5086324E-011$
 Shear Force, $V_b = 1.4226804E-014$
 BOTH EDGES
 Axial Force, $F = -4770.122$
 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: $As_{c,mid} = 1017.876$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = *V_n = 267605.60$
 V_n ((10.3), ASCE 41-17) = $knI * V_{Col} = 314830.118$
 $V_{Col} = 314830.118$
 $knI = 1.00$
 displacement_ductility_demand = 0.00

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)
 $f'_c = 16.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 1.5086324E-011$
 $V_u = 1.4226804E-014$
 $d = 0.8 * D = 320.00$
 $N_u = 4770.122$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 157913.67$
 $A_v = /2 * A_{stirrup} = 123370.055$
 $f_y = 400.00$
 $s = 100.00$
 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

$wf/sf = 1$ (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 $Vf(\theta)$, 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: $\theta = b1 + 90^\circ = 90.00$

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

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

$dfv = d$ (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: $Vs + Vf \leq 213705.936$

$bw \cdot d = \frac{V}{\phi \cdot f_v} = 80424.772$

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 $\theta = 2.6179514E-022$

$y = (My \cdot Ls / 3) / Eleff = 0.008665$ ((4.29), Biskinis Phd))

$My = 1.3732E+008$

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

From table 10.5, ASCE 41_17: $Eleff = \text{factor} \cdot Ec \cdot Ig = 7.9240E+012$

factor = 0.30

$Ag = 125663.706$

$fc' = 20.00$

$N = 4770.122$

$Ec \cdot Ig = 2.6413E+013$

Calculation of Yielding Moment My

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

$My = \text{Min}(My_{ten}, My_{com}) = 1.3732E+008$

$y = 7.5716684E-006$

My_{ten} (8c) = 1.3732E+008

$_{ten}$ (7c) = 72.23345

error of function (7c) = 0.00097594

My_{com} (8d) = 3.7493E+008

$_{com}$ (7d) = 69.91126

error of function (7d) = 0.00301333

with ((10.1), ASCE 41-17) $ey = \text{Min}(ey, 1.25 \cdot ey \cdot (lb/ld)^{2/3}) = 0.00222222$

$eco = 0.002$

$apl = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)

$d1 = 44.00$

$R = 200.00$

$v = 0.00157314$

$N = 4770.122$

$Ac = 125663.706$

((10.1), ASCE 41-17) $= \text{Min}(\quad, 1.25 \cdot \quad \cdot (lb/ld)^{2/3}) = 0.44758025$

with fc' ((12.3), ACI 440) = 24.12975

$fc = 20.00$

$fl = 1.3173$

$k = 1$

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

efe ((12.5) and (12.7)) = 0.004

$fu = 0.01$

$Ef = 64828.00$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

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

At local axis: 3

Integration Section: (b)

Calculation No. 8

column C1, Floor 1

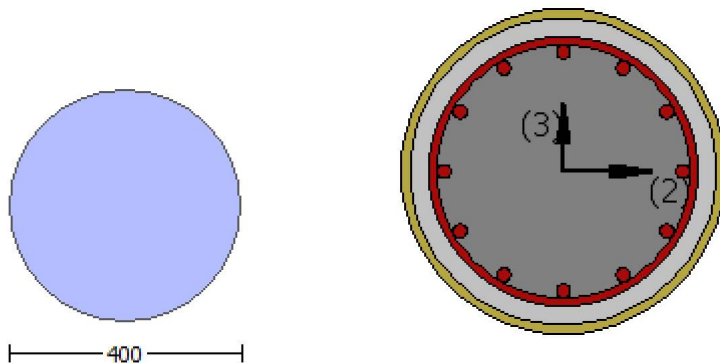
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (μ)

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, $\gamma = 0.85$

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

Diameter, $D = 400.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.84055
 Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{o,min} = 0.30$
 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, $N_{oDir} = 1$
 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, $V_a = -3.7968243E-031$
 EDGE -B-
 Shear Force, $V_b = 3.7968243E-031$
 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 , $V_e/V_r = 0.27402927$
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96425.251$
 with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 1.4464E+008$
 $\mu_{u1+} = 1.4464E+008$, 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
 $\mu_{u1-} = 1.4464E+008$, 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
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 1.4464E+008$
 $\mu_{u2+} = 1.4464E+008$, 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
 $\mu_{u2-} = 1.4464E+008$, 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
 $\mu_u = 1.4464E+008$
 $= 0.9250245$

' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 36.81095$
conf. factor $c = 1.84055$
 $f_c = 20.00$
From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_1 -

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 1.4464E+008$

= 0.9250245
' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 36.81095$
conf. factor $c = 1.84055$
 $f_c = 20.00$
From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_2 +

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 1.4464E+008$

= 0.9250245
' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 36.81095$
conf. factor $c = 1.84055$
 $f_c = 20.00$
From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$

$$v = 0.00155946$$

$$N = 4771.233$$

$$Ac = 125663.706$$

$$= *Min(1, 1.25*(lb/d)^{2/3}) = 0.31060654$$

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

$$= 0.9250245$$

$$' = 0.82105152$$

error of function (3.68), Biskinis Phd = 31682.903

From 5A.2, TBDY: $f_{cc} = f_c' \cdot c = 36.81095$

conf. factor $c = 1.84055$

$f_c = 20.00$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y * Min(1, 1.25*(lb/d)^{2/3}) = 311.2087$

lb/d = 0.30

d1 = 44.00

R = 200.00

v = 0.00155946

N = 4771.233

Ac = 125663.706

$$= *Min(1, 1.25*(lb/d)^{2/3}) = 0.31060654$$

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Shear Strength $V_r = Min(V_{r1}, V_{r2}) = 351879.387$

Calculation of Shear Strength at edge 1, $V_{r1} = 351879.387$

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

$V_{Col0} = 351879.387$

$k_n l = 1$ (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).

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

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

$M/Vd = 2.00$

$M_u = 9.8466009E-012$

$V_u = 3.7968243E-031$

$d = 0.8 * D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 175459.634$

$A_v = /2 * A_{stirrup} = 123370.055$

$f_y = 444.4444$

$s = 100.00$

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) $\sin \theta + \cos \theta$ 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: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
 total thickness per orientation, $tf1 = NL * t / NoDir = 1.016$
 $d_{fv} = d$ (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: $V_s + V_f \leq 238930.50$
 $bw * d = \rho * d^2 / 4 = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 351879.387$
 $V_{r2} = V_{Col} ((10.3), \text{ASCE 41-17}) = knl * V_{Col0}$
 $V_{Col0} = 351879.387$
 $knl = 1$ (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)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M / Vd = 2.00$
 $\mu_u = 9.8466009E-012$
 $\nu_u = 3.7968243E-031$
 $d = 0.8 * D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 175459.634$
 $A_v = \rho_s / 2 * A_{stirrup} = 123370.055$
 $f_y = 444.4444$
 $s = 100.00$
 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
 $wf/sf = 1$ (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: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
 total thickness per orientation, $tf1 = NL * t / NoDir = 1.016$
 $d_{fv} = d$ (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: $V_s + V_f \leq 238930.50$
 $bw * d = \rho * d^2 / 4 = 80424.772$

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, $\phi = 0.85$

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.84055

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

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, $V_a = 4.4296389E-033$

EDGE -B-

Shear Force, $V_b = -4.4296389E-033$

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, $V_e/V_r = 0.27402927$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96425.251$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.4464E+008$

$M_{u1+} = 1.4464E+008$, 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

Mu1- = 1.4464E+008, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
Mpr2 = Max(Mu2+ , Mu2-) = 1.4464E+008
Mu2+ = 1.4464E+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
Mu2- = 1.4464E+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 Mu1+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

= 0.9250245
' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: fcc = fc* c = 36.81095
conf. factor c = 1.84055
fc = 20.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 311.2087
lb/d = 0.30
d1 = 44.00
R = 200.00
v = 0.00155946
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.31060654

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

= 0.9250245
' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: fcc = fc* c = 36.81095
conf. factor c = 1.84055
fc = 20.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 311.2087
lb/d = 0.30
d1 = 44.00
R = 200.00
v = 0.00155946
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.31060654

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

= 0.9250245
' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: fcc = fc* c = 36.81095
conf. factor c = 1.84055
fc = 20.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 311.2087
lb/d = 0.30
d1 = 44.00
R = 200.00
v = 0.00155946
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.31060654

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

= 0.9250245
' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: fcc = fc* c = 36.81095
conf. factor c = 1.84055
fc = 20.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 311.2087
lb/d = 0.30
d1 = 44.00
R = 200.00
v = 0.00155946
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.31060654

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 351879.387

Calculation of Shear Strength at edge 1, Vr1 = 351879.387

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

VColO = 351879.387

knl = 1 (zero step-static loading)

NOTE: In expression (10-3) 'Vs = Av*fy*d/s' is replaced by 'Vs+ f*VF'

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

$= 1$ (normal-weight concrete)

$f'_c = 20.00$, but $f'_c \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 9.0356326E-012$

$\nu_u = 4.4296389E-033$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 175459.634$

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

$f_y = 444.4444$

$s = 100.00$

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: $\theta = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, 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), 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: $V_s + V_f \leq 238930.50$

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

Calculation of Shear Strength at edge 2, $V_{r2} = 351879.387$

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

$V_{\text{Col}0} = 351879.387$

$k_{nl} = 1$ (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)

$f'_c = 20.00$, but $f'_c \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 9.0356326E-012$

$\nu_u = 4.4296389E-033$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 175459.634$

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

$f_y = 444.4444$

$s = 100.00$

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: $\theta = b_1 + 90^\circ = 90.00$

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

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

dfv = 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 <= 238930.50
bw*d = *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: 3
Integration Section: (b)
Section Type: rccs

Constant Properties

Knowledge Factor, = 0.85
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Primary Member: Concrete Strength, fc = fcm = 20.00
Existing material of Primary Member: Steel Strength, fs = fsm = 444.4444
Concrete Elasticity, Ec = 21019.039
Steel Elasticity, Es = 200000.00
Diameter, D = 400.00
Cover Thickness, c = 25.00
Element Length, L = 3000.00
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with lb/ld = 0.30
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

Bending Moment, M = 0.07583332
Shear Force, V2 = 2777.007
Shear Force, V3 = 1.4226804E-014
Axial Force, F = -4770.122
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 3053.628
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

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $\phi_R = \phi_y + \phi_p = 0.00147305$

- Calculation of ϕ_y -

$\phi_y = (M_y \cdot L_s / 3) / E_{eff} = 0.001733$ ((4.29), Biskinis Phd))
 $M_y = 1.3732E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 7.9240E+012$
 $factor = 0.30$
 $A_g = 125663.706$
 $f_c' = 20.00$
 $N = 4770.122$
 $E_c \cdot I_g = 2.6413E+013$

Calculation of Yielding Moment M_y

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

$M_y = \min(M_{y_ten}, M_{y_com}) = 1.3732E+008$
 $\phi_y = 7.5716684E-006$
 M_{y_ten} (8c) = 1.3732E+008
 ϕ_{y_ten} (7c) = 72.23345
error of function (7c) = 0.00097594
 M_{y_com} (8d) = 3.7493E+008
 ϕ_{y_com} (7d) = 69.91126
error of function (7d) = 0.00301333
with ((10.1), ASCE 41-17) $\phi_y = \min(\phi_y, 1.25 \cdot \phi_y \cdot (l_b / l_d)^{2/3}) = 0.00222222$
 $\phi_{eco} = 0.002$
 $\phi_{apl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00157314$
 $N = 4770.122$
 $A_c = 125663.706$
((10.1), ASCE 41-17) $\phi_y = \min(\phi_y, 1.25 \cdot \phi_y \cdot (l_b / l_d)^{2/3}) = 0.44758025$
with $\phi_c \cdot ((12.3), ACI 440) = 24.12975$
 $\phi_c = 20.00$
 $\phi_l = 1.3173$
 $k = 1$
Effective FRP thickness, $t_f = N \cdot L \cdot t \cdot \cos(\theta) = 1.016$
 ϕ_{efe} ((12.5) and (12.7)) = 0.004
 $\phi_u = 0.01$
 $E_f = 64828.00$

Calculation of ratio l_b / l_d

Inadequate Lap Length with $l_b / l_d = 0.30$

- Calculation of ϕ_p -

From table 10-9: $\phi_p = 0.00$

with:

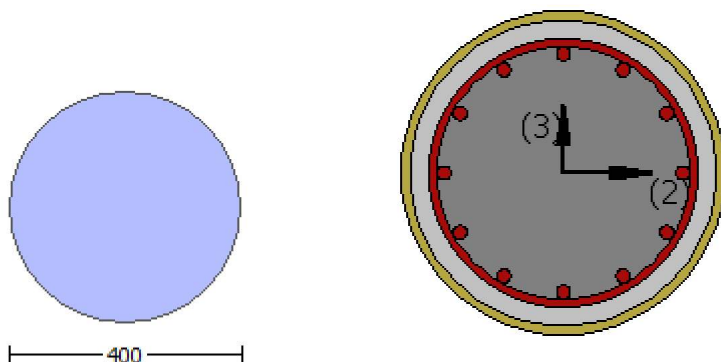
- Columns not controlled by inadequate development or splicing along the clear height because $l_b / l_d \geq 1$
shear control ratio $V_y E / V_{col} E = 0.27402927$
 $d = 0.00$
 $s = 0.00$
 $t = 2 \cdot A_v / (d_c \cdot s) + 4 \cdot t_f / D \cdot (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$, 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.
 $N_{UD} = 4770.122$
 $A_g = 125663.706$
 $f_{cE} = 20.00$
 $f_{tE} = f_{yE} = 444.4444$
 $\rho_l = \text{Area_Tot_Long_Rein} / (A_g) = 0.0243$
 $f_{cE} = 20.00$

 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 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, $\gamma = 0.85$
 Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.
 Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of γ for displacement ductility demand,
 the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as
 Deformation-Controlled Action (Table C7-1, ASCE41-17).
 Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$
 #####
 Diameter, $D = 400.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou,min} = l_b/l_d = 0.30$
 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

EDGE -A-
 Bending Moment, $M_a = -1.0423E+007$
 Shear Force, $V_a = -3472.529$
 EDGE -B-
 Bending Moment, $M_b = 0.09482631$
 Shear Force, $V_b = 3472.529$
 BOTH EDGES
 Axial Force, $F = -4769.844$
 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, $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41-17: Final Shear Capacity $V_R = \phi V_n = 224627.799$
 V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoI} = 264267.999$
 $V_{CoI} = 264267.999$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.02032763$

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

 $\phi = 1$ (normal-weight concrete)
 $f'_c = 16.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$

$\mu = 1.0423E+007$
 $V_u = 3472.529$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4769.844$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 157913.67$
 $A_v = \frac{1}{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 400.00$
 $s = 100.00$
 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 $V_f(\theta, a)$, 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: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / \text{NoDir} = 1.016$
 $dfv = d$ (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: $V_s + V_f \leq 213705.936$
 $bw \cdot d = \frac{V_s \cdot d}{4} = 80424.772$

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 $\phi = 0.00035245$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.01733835$ ((4.29), Biskinis Phd))
 $M_y = 1.3732E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 3001.447
 From table 10.5, ASCE 41-17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 7.9240E+012$
 $\text{factor} = 0.30$
 $A_g = 125663.706$
 $f_c' = 20.00$
 $N = 4769.844$
 $E_c \cdot I_g = 2.6413E+013$

Calculation of Yielding Moment M_y

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

$M_y = \text{Min}(M_{y_ten}, M_{y_com}) = 1.3732E+008$
 $y = 7.5716672E-006$
 $M_{y_ten} (8c) = 1.3732E+008$
 $\delta_{ten} (7c) = 72.23344$
 error of function (7c) = 0.00097593
 $M_{y_com} (8d) = 3.7493E+008$
 $\delta_{com} (7d) = 69.91126$
 error of function (7d) = 0.00301342
 with ((10.1), ASCE 41-17) $e_y = \text{Min}(e_y, 1.25 \cdot e_y \cdot (I_b / I_d)^{2/3}) = 0.00222222$
 $e_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d1 = 44.00$
 $R = 200.00$
 $v = 0.00157305$

$N = 4769.844$
 $A_c = 125663.706$
 $((10.1), ASCE\ 41-17) = \text{Min}(, 1.25 * ((lb/ld)^{2/3}) = 0.44758025$
 with $f_c^* ((12.3), ACI\ 440) = 24.12975$
 $f_c = 20.00$
 $f_l = 1.3173$
 $k = 1$
 Effective FRP thickness, $t_f = NL * t * \text{Cos}(b1) = 1.016$
 $e_{fe} ((12.5) \text{ and } (12.7)) = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

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

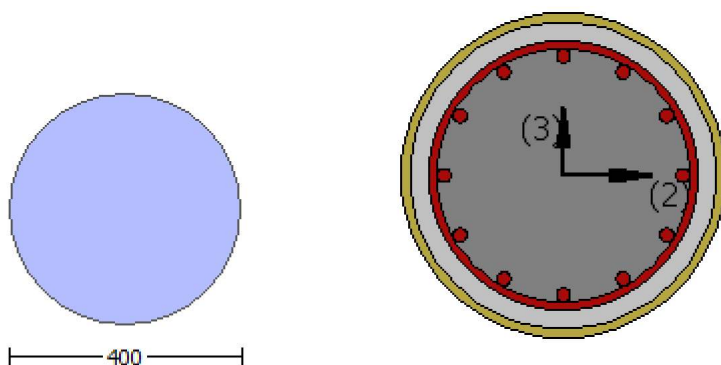
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

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, $\phi = 0.85$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$
 #####
 Diameter, $D = 400.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.84055
 Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
 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, $V_a = -3.7968243E-031$
 EDGE -B-
 Shear Force, $V_b = 3.7968243E-031$
 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, $V_e/V_r = 0.27402927$
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96425.251$
 with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.4464E+008$
 $M_{u1+} = 1.4464E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
 which is defined for the static loading combination
 $M_{u1-} = 1.4464E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
 direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.4464E+008$
 $M_{u2+} = 1.4464E+008$, 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

Mu2- = 1.4464E+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 Mu1+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

$$= 0.9250245$$

$$' = 0.82105152$$

error of function (3.68), Biskinis Phd = 31682.903

From 5A.2, TDY: fcc = fc* c = 36.81095

conf. factor c = 1.84055

fc = 20.00

From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 311.2087

$$lb/d = 0.30$$

$$d1 = 44.00$$

$$R = 200.00$$

$$v = 0.00155946$$

$$N = 4771.233$$

$$Ac = 125663.706$$

$$= *Min(1,1.25*(lb/d)^ 2/3) = 0.31060654$$

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

$$= 0.9250245$$

$$' = 0.82105152$$

error of function (3.68), Biskinis Phd = 31682.903

From 5A.2, TDY: fcc = fc* c = 36.81095

conf. factor c = 1.84055

fc = 20.00

From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 311.2087

$$lb/d = 0.30$$

$$d1 = 44.00$$

$$R = 200.00$$

$$v = 0.00155946$$

$$N = 4771.233$$

$$Ac = 125663.706$$

$$= *Min(1,1.25*(lb/d)^ 2/3) = 0.31060654$$

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

= 0.9250245
' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: fcc = fc* c = 36.81095
conf. factor c = 1.84055
fc = 20.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 311.2087
lb/d = 0.30
d1 = 44.00
R = 200.00
v = 0.00155946
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.31060654

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

= 0.9250245
' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: fcc = fc* c = 36.81095
conf. factor c = 1.84055
fc = 20.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 311.2087
lb/d = 0.30
d1 = 44.00
R = 200.00
v = 0.00155946
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.31060654

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 351879.387

Calculation of Shear Strength at edge 1, Vr1 = 351879.387

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

VCol0 = 351879.387

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).

= 1 (normal-weight concrete)
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$
 $\mu_u = 9.8466009E-012$
 $\mu_v = 3.7968243E-031$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 175459.634$
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 444.4444$
 $s = 100.00$
 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 $V_f(\theta, a)$, 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: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (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: $V_s + V_f \leq 238930.50$
 $b_w \cdot d = \sqrt{2} \cdot d \cdot d / 4 = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 351879.387$
 $V_{r2} = V_{Col} ((10.3), \text{ASCE } 41-17) = k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 351879.387$
 $k_{nl} = 1$ (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).

$\mu = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 9.8466009E-012$
 $\mu_v = 3.7968243E-031$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 175459.634$
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 444.4444$
 $s = 100.00$
 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 $V_f(\theta, a)$, 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: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (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: $V_s + V_f \leq 238930.50$
 $b_w d = \frac{A_s f_u}{f_y} = 80424.772$

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, $\phi = 0.85$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$

Diameter, $D = 400.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.84055
Element Length, $L = 3000.00$
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_o/l_{o,min} = 0.30$
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, $V_a = 4.4296389E-033$
EDGE -B-
Shear Force, $V_b = -4.4296389E-033$
BOTH EDGES
Axial Force, $F = -4771.233$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl} = 0.00$
-Compression: $A_{slc} = 3053.628$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 1017.876$

-Compression: $A_s l_{com} = 1017.876$
-Middle: $A_s l_{mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.27402927$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96425.251$
with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.4464E+008$

$M_{u1+} = 1.4464E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 1.4464E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.4464E+008$

$M_{u2+} = 1.4464E+008$, 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

$M_{u2-} = 1.4464E+008$, 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
 $M_u = 1.4464E+008$

$\phi = 0.9250245$

$\lambda = 0.82105152$

error of function (3.68), Biskinis Phd = 31682.903

From 5A.2, TB DY: $f_{cc} = f_c^* \quad c = 36.81095$

conf. factor $c = 1.84055$

$f_c = 20.00$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y * \text{Min}(1, 1.25 * (l_b/l_d)^{2/3}) = 311.2087$

$l_b/l_d = 0.30$

$d_1 = 44.00$

$R = 200.00$

$v = 0.00155946$

$N = 4771.233$

$A_c = 125663.706$

$= * \text{Min}(1, 1.25 * (l_b/l_d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u1-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), M_u
 $M_u = 1.4464E+008$

$\phi = 0.9250245$

$\lambda = 0.82105152$

error of function (3.68), Biskinis Phd = 31682.903

From 5A.2, TB DY: $f_{cc} = f_c^* \quad c = 36.81095$

conf. factor $c = 1.84055$

$f_c = 20.00$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y * \text{Min}(1, 1.25 * (l_b/l_d)^{2/3}) = 311.2087$

$l_b/l_d = 0.30$

$d_1 = 44.00$

R = 200.00
v = 0.00155946
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.31060654

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

= 0.9250245
' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: fcc = fc* c = 36.81095
conf. factor c = 1.84055
fc = 20.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 311.2087
lb/d = 0.30
d1 = 44.00
R = 200.00
v = 0.00155946
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.31060654

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

= 0.9250245
' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: fcc = fc* c = 36.81095
conf. factor c = 1.84055
fc = 20.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 311.2087
lb/d = 0.30
d1 = 44.00
R = 200.00
v = 0.00155946
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.31060654

Calculation of ratio lb/d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 351879.387$

Calculation of Shear Strength at edge 1, $V_{r1} = 351879.387$

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

$V_{\text{ColO}} = 351879.387$

$k_{nl} = 1$ (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)

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

$M/Vd = 2.00$

$\mu_u = 9.0356326\text{E-}012$

$V_u = 4.4296389\text{E-}033$

$d = 0.8 * D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 175459.634$

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

$f_y = 444.4444$

$s = 100.00$

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

$s/d = 0.3125$

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

$f = 0.95$, 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 $V_f(\theta, a)$, 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: $\theta = b1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$ (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: $V_s + V_f \leq 238930.50$

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

Calculation of Shear Strength at edge 2, $V_{r2} = 351879.387$

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

$V_{\text{ColO}} = 351879.387$

$k_{nl} = 1$ (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)

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

$M/Vd = 2.00$

$\mu_u = 9.0356326\text{E-}012$

$V_u = 4.4296389\text{E-}033$

$d = 0.8 * D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 175459.634$

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

$f_y = 444.4444$

$s = 100.00$
 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 $V_f(\theta, a)$, 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: $V_s + V_f \leq 238930.50$
 $b_w * d = \frac{V_s * d}{4} = 80424.772$

 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, $\phi = 0.85$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 Diameter, $D = 400.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_b/l_d = 0.30$
 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, $\text{NoDir} = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 3.1953177\text{E-}011$
 Shear Force, $V2 = -3472.529$
 Shear Force, $V3 = -1.7790009\text{E-}014$
 Axial Force, $F = -4769.844$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_{lt} = 1272.345$
 -Compression: $As_{lc} = 1781.283$
 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, $DbL = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = u = 0.04306525$
 $u = y + p = 0.050665$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.008665$ ((4.29), Biskinis Phd))
 $M_y = 1.3732\text{E+}008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 7.9240\text{E+}012$
 factor = 0.30
 $A_g = 125663.706$
 $f_c' = 20.00$
 $N = 4769.844$
 $E_c * I_g = 2.6413\text{E+}013$

Calculation of Yielding Moment M_y

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

$M_y = \text{Min}(M_{y_ten}, M_{y_com}) = 1.3732\text{E+}008$
 $y = 7.5716672\text{E-}006$
 $M_{y_ten} (8c) = 1.3732\text{E+}008$
 $_{ten} (7c) = 72.23344$
 error of function (7c) = 0.00097593
 $M_{y_com} (8d) = 3.7493\text{E+}008$
 $_{com} (7d) = 69.91126$
 error of function (7d) = 0.00301342
 with ((10.1), ASCE 41-17) $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.00222222$
 $e_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d1 = 44.00$
 $R = 200.00$
 $v = 0.00157305$
 $N = 4769.844$
 $A_c = 125663.706$
 ((10.1), ASCE 41-17) $= \text{Min}(, 1.25 * (l_b / l_d)^{2/3}) = 0.44758025$
 with $f_c' ((12.3), \text{ACI } 440) = 24.12975$
 $f_c = 20.00$
 $f_l = 1.3173$
 $k = 1$
 Effective FRP thickness, $t_f = N L * t * \text{Cos}(b1) = 1.016$
 $e_{fe} ((12.5) \text{ and } (12.7)) = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$

Calculation of ratio l_b / l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

- Calculation of p -

From table 10-9: $p = 0.042$

with:

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

shear control ratio $V_y E / V_{Col0E} = 0.27402927$

$d = 0.00$

$s = 0.00$

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

$A_v = 78.53982$, 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.

$NUD = 4769.844$

$Ag = 125663.706$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 444.4444$

$p_l = \text{Area_Tot_Long_Rein} / (Ag) = 0.0243$

$f_{cE} = 20.00$

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

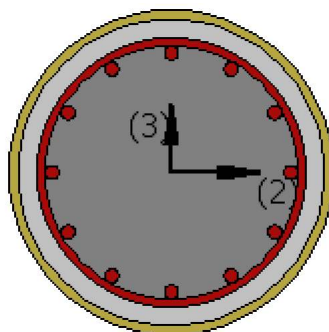
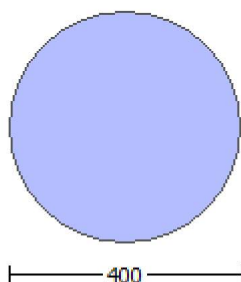
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity 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, $\gamma = 0.85$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

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, $M_a = 3.1953177E-011$

Shear Force, $V_a = -1.7790009E-014$

EDGE -B-

Bending Moment, $M_b = 2.1330954E-011$

Shear Force, $V_b = 1.7790009E-014$

BOTH EDGES

Axial Force, $F = -4769.844$

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, $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = V_n = 267605.553$
 V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoI} = 314830.062$
 $V_{CoI} = 314830.062$
 $k_n = 1.00$
 $\text{displacement_ductility_demand} = 0.00$

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).

$f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 3.1953177E-011$
 $\mu_v = 1.7790009E-014$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4769.844$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 157913.67$
 $A_v = \frac{1}{2} \cdot A_{\text{stirrup}} = 123370.055$
 $f_y = 400.00$
 $s = 100.00$
 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 $V_f(\theta, a)$, 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: $\theta = 45^\circ$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, 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
 $E_f = 64828.00$
 $f_{fe} = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 213705.936$
 $b_w \cdot d = \frac{V_s + V_f}{f_{fe} \cdot E_f} = 80424.772$

$\text{displacement_ductility_demand}$ is calculated as $\frac{\phi}{\gamma}$

- Calculation of $\frac{\phi}{\gamma}$ for END A -
 for rotation axis 2 and integ. section (a)

From analysis, chord rotation $\phi = 5.9951039E-021$
 $\gamma = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.008665$ ((4.29), Biskinis Phd))
 $M_y = 1.3732E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00
 From table 10.5, ASCE 41_17: $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 7.9240E+012$
 $\text{factor} = 0.30$
 $A_g = 125663.706$
 $f_c' = 20.00$
 $N = 4769.844$
 $E_c \cdot I_g = 2.6413E+013$

Calculation of Yielding Moment M_y

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

$M_y = \text{Min}(M_{y_{\text{ten}}}, M_{y_{\text{com}}}) = 1.3732E+008$

$y = 7.5716672E-006$
 $M_{y_ten} (8c) = 1.3732E+008$
 $_{ten} (7c) = 72.23344$
error of function (7c) = 0.00097593
 $M_{y_com} (8d) = 3.7493E+008$
 $_{com} (7d) = 69.91126$
error of function (7d) = 0.00301342
with ((10.1), ASCE 41-17) $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.00222222$
 $e_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00157305$
 $N = 4769.844$
 $A_c = 125663.706$
((10.1), ASCE 41-17) $= \text{Min}(, 1.25 * (l_b / l_d)^{2/3}) = 0.44758025$
with f_c^* ((12.3), ACI 440) = 24.12975
 $f_c = 20.00$
 $f_l = 1.3173$
 $k = 1$
Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $f_u = 0.01$
 $E_f = 64828.00$

Calculation of ratio l_b / l_d

Inadequate Lap Length with $l_b / l_d = 0.30$

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

At local axis: 3

Integration Section: (a)

Calculation No. 12

column C1, Floor 1

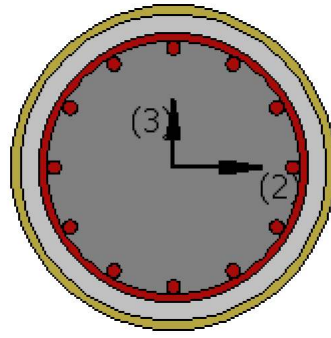
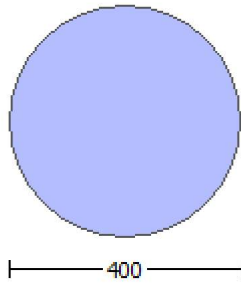
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_u)

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, $\gamma = 0.85$

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.84055

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$

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

At local axis: 3

EDGE -A-

Shear Force, $V_a = -3.7968243E-031$

EDGE -B-

Shear Force, $V_b = 3.7968243E-031$

BOTH EDGES

Axial Force, $F = -4771.233$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: Aslt = 0.00
 -Compression: Aslc = 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 , $V_e/V_r = 0.27402927$
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96425.251$
 with
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 1.4464E+008$
 $\mu_{1+} = 1.4464E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
 which is defined for the static loading combination
 $\mu_{1-} = 1.4464E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
 direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 1.4464E+008$
 $\mu_{2+} = 1.4464E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
 which is defined for the static loading combination
 $\mu_{2-} = 1.4464E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment
 direction which is defined for the static loading combination

Calculation of μ_{1+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ_u
 $\mu_u = 1.4464E+008$

$\phi = 0.9250245$
 $\lambda = 0.82105152$
 error of function (3.68), Biskinis Phd = 31682.903
 From 5A.2, TDY: $f_{cc} = f_c \cdot c = 36.81095$
 conf. factor $c = 1.84055$
 $f_c = 20.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $\phi \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_{1-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ_u
 $\mu_u = 1.4464E+008$

$\phi = 0.9250245$
 $\lambda = 0.82105152$
 error of function (3.68), Biskinis Phd = 31682.903
 From 5A.2, TDY: $f_{cc} = f_c \cdot c = 36.81095$
 conf. factor $c = 1.84055$

$f_c = 20.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_{2+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 1.4464E+008$

$= 0.9250245$
 $' = 0.82105152$
 error of function (3.68), Biskinis Phd = 31682.903
 From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 36.81095$
 conf. factor $c = 1.84055$
 $f_c = 20.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_{2-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 1.4464E+008$

$= 0.9250245$
 $' = 0.82105152$
 error of function (3.68), Biskinis Phd = 31682.903
 From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 36.81095$
 conf. factor $c = 1.84055$
 $f_c = 20.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 351879.387$

Calculation of Shear Strength at edge 1, $V_{r1} = 351879.387$

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

$V_{Col0} = 351879.387$

$k_n l = 1$ (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).

$= 1$ (normal-weight concrete)

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

$M/Vd = 2.00$

$\mu_u = 9.8466009E-012$

$\nu_u = 3.7968243E-031$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 175459.634$

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

$f_y = 444.4444$

$s = 100.00$

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

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, 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: $V_s + V_f \leq 238930.50$

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

Calculation of Shear Strength at edge 2, $V_{r2} = 351879.387$

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

$V_{Col0} = 351879.387$

$k_n l = 1$ (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).

$= 1$ (normal-weight concrete)

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

$M/Vd = 2.00$

$\mu_u = 9.8466009E-012$

$\nu_u = 3.7968243E-031$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 175459.634$
 $A_v = \frac{1}{2} A_{stirrup} = 123370.055$
 $f_y = 444.4444$
 $s = 100.00$
 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: $\theta_1 = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (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: $V_s + V_f \leq 238930.50$
 $b_w * d = \frac{1}{4} * d * d = 80424.772$

 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, $\phi = 0.85$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 * f_{sm} = 555.5556$
 #####
 Diameter, $D = 400.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.84055
 Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou, \min} = 0.30$
 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, $bi = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 4.4296389E-033$
EDGE -B-
Shear Force, $V_b = -4.4296389E-033$
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, $V_e/V_r = 0.27402927$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96425.251$
with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 1.4464E+008$
 $\mu_{u1+} = 1.4464E+008$, 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
 $\mu_{u1-} = 1.4464E+008$, 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
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 1.4464E+008$
 $\mu_{u2+} = 1.4464E+008$, 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
 $\mu_{u2-} = 1.4464E+008$, 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
 $\mu_u = 1.4464E+008$

$\phi = 0.9250245$
 $\phi' = 0.82105152$
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 36.81095$
conf. factor $c = 1.84055$
 $f_c = 20.00$
From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \min(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $\phi' \cdot \min(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{1-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 1.4464E+008$

$\phi = 0.9250245$
 $\phi' = 0.82105152$
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TDY: $f_{cc} = f_c \cdot c = 36.81095$
conf. factor $c = 1.84055$
 $f_c = 20.00$
From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 311.2087$
 $l_b/l_d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $\phi \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{2+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 1.4464E+008$

$\phi = 0.9250245$
 $\phi' = 0.82105152$
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TDY: $f_{cc} = f_c \cdot c = 36.81095$
conf. factor $c = 1.84055$
 $f_c = 20.00$
From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 311.2087$
 $l_b/l_d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $\phi \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{2-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), M_u
 $M_u = 1.4464E+008$

$= 0.9250245$
 $' = 0.82105152$
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: $f_{cc} = f_c' \cdot c = 36.81095$
conf. factor $c = 1.84055$
 $f_c = 20.00$
From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 311.2087$
 $l_b/l_d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 351879.387$

Calculation of Shear Strength at edge 1, $V_{r1} = 351879.387$
 $V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{ColO}$
 $V_{ColO} = 351879.387$
 $k_{nl} = 1$ (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)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 9.0356326E-012$
 $V_u = 4.4296389E-033$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
From (11.5.4.8), ACI 318-14: $V_s = 175459.634$
 $A_v = \frac{1}{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 444.4444$
 $s = 100.00$
 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: $\theta_1 = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:
total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (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: $V_s + V_f \leq 238930.50$
 $b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 351879.387$

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

$V_{Col0} = 351879.387$

$k_{nl} = 1$ (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).

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

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

$M/Vd = 2.00$

$\mu_u = 9.0356326E-012$

$\nu_u = 4.4296389E-033$

$d = 0.8 * D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14: $V_s = 175459.634$

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

$f_y = 444.4444$

$s = 100.00$

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

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

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

$d_{fv} = d$ (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: $V_s + V_f \leq 238930.50$

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

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: 3

Integration Section: (a)

Section Type: rccs

Constant Properties

Knowledge Factor, $\lambda = 0.85$

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

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_b/l_d = 0.30$
 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, $M = -1.0423E+007$
 Shear Force, $V_2 = -3472.529$
 Shear Force, $V_3 = -1.7790009E-014$
 Axial Force, $F = -4769.844$
 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, $D_{bL} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = u = 0.0504376$
 $u = y + p = 0.05933835$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.01733835$ ((4.29), Biskinis Phd))
 $M_y = 1.3732E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3001.447
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 7.9240E+012$
 factor = 0.30
 $A_g = 125663.706$
 $f_c' = 20.00$
 $N = 4769.844$
 $E_c * I_g = 2.6413E+013$

Calculation of Yielding Moment M_y

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

$M_y = \min(M_{y_ten}, M_{y_com}) = 1.3732E+008$
 $y = 7.5716672E-006$
 $M_{y_ten} (8c) = 1.3732E+008$
 $_{ten} (7c) = 72.23344$
 error of function (7c) = 0.00097593
 $M_{y_com} (8d) = 3.7493E+008$
 $_{com} (7d) = 69.91126$
 error of function (7d) = 0.00301342

with ((10.1), ASCE 41-17) $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.00222222$

$e_{co} = 0.002$

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

$d_1 = 44.00$

$R = 200.00$

$v = 0.00157305$

$N = 4769.844$

$A_c = 125663.706$

((10.1), ASCE 41-17) $= \text{Min}(, 1.25 * (l_b / l_d)^{2/3}) = 0.44758025$

with f_c^* ((12.3), ACI 440) = 24.12975

$f_c = 20.00$

$f_l = 1.3173$

$k = 1$

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

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

$f_u = 0.01$

$E_f = 64828.00$

Calculation of ratio l_b / l_d

Inadequate Lap Length with $l_b / l_d = 0.30$

- Calculation of p -

From table 10-9: $p = 0.042$

with:

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

shear control ratio $V_y E / V_{col} O E = 0.27402927$

$d = 0.00$

$s = 0.00$

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

$A_v = 78.53982$, 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.

$N_{UD} = 4769.844$

$A_g = 125663.706$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 444.4444$

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

$f_{cE} = 20.00$

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

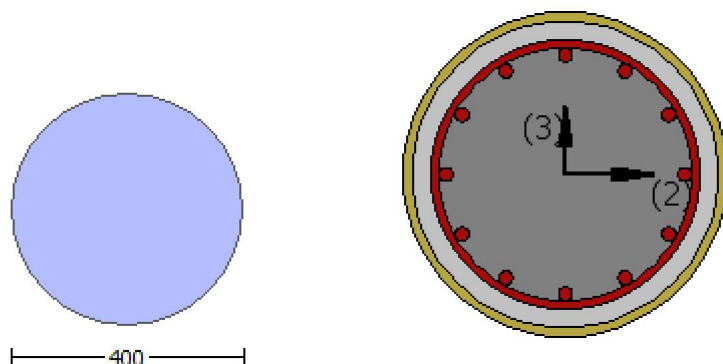
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

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, $\gamma = 0.85$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

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, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

EDGE -A-
Bending Moment, Ma = -1.0423E+007
Shear Force, Va = -3472.529
EDGE -B-
Bending Moment, Mb = 0.09482631
Shear Force, Vb = 3472.529
BOTH EDGES
Axial Force, F = -4769.844
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 3053.628
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,ten = 18.00

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity VR = *Vn = 267605.553
Vn ((10.3), ASCE 41-17) = knl*VCol0 = 314830.062
VCol = 314830.062
knl = 1.00
displacement_ductility_demand = 0.11383644

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).

= 1 (normal-weight concrete)
fc' = 16.00, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
M/Vd = 2.00
Mu = 0.09482631
Vu = 3472.529
d = 0.8*D = 320.00
Nu = 4769.844
Ag = 125663.706
From (11.5.4.8), ACI 318-14: Vs = 157913.67
Av = /2*A_stirrup = 123370.055
fy = 400.00
s = 100.00
Vs is multiplied by Col = 0.00
s/d = 0.3125
Vf ((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 is the angle of the crack direction (see KANEPE).
This later relation, considered as a function Vf(,), is implemented for every different fiber orientation ai,
as well as for 2 crack directions, =45° and =-45° to take into consideration the cyclic seismic loading.
orientation 1: 1 = b1 + 90° = 90.00
Vf = Min(|Vf(45, 1)|, |Vf(-45,a1)|), with:
total thickness per orientation, tf1 = NL*t/NoDir = 1.016
dfv = 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 <= 213705.936
bw*d = *d*d/4 = 80424.772

displacement_ductility_demand is calculated as ϕ / y

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

From analysis, chord rotation $\theta = 0.00019728$
 $y = (M_y * L_s / 3) / E_{eff} = 0.001733$ ((4.29), Biskinis Phd))
 $M_y = 1.3732E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 7.9240E+012$
factor = 0.30
Ag = 125663.706
fc' = 20.00
N = 4769.844
 $E_c * I_g = 2.6413E+013$

Calculation of Yielding Moment M_y

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

$M_y = \min(M_{y_ten}, M_{y_com}) = 1.3732E+008$
 $y = 7.5716672E-006$
 $M_{y_ten} (8c) = 1.3732E+008$
 $\phi_{ten} (7c) = 72.23344$
error of function (7c) = 0.00097593
 $M_{y_com} (8d) = 3.7493E+008$
 $\phi_{com} (7d) = 69.91126$
error of function (7d) = 0.00301342
with ((10.1), ASCE 41-17) $e_y = \min(e_y, 1.25 * e_y * (I_b / I_d)^{2/3}) = 0.00222222$
eco = 0.002
apl = 0.45 ((9c) in Biskinis and Fardis for FRP Wrap)
d1 = 44.00
R = 200.00
v = 0.00157305
N = 4769.844
Ac = 125663.706
((10.1), ASCE 41-17) $\phi = \min(\phi, 1.25 * \phi * (I_b / I_d)^{2/3}) = 0.44758025$
with fc' ((12.3), ACI 440) = 24.12975
fc = 20.00
fl = 1.3173
k = 1
Effective FRP thickness, tf = NL * t * Cos(b1) = 1.016
efe ((12.5) and (12.7)) = 0.004
fu = 0.01
Ef = 64828.00

Calculation of ratio I_b / I_d

Inadequate Lap Length with $I_b / I_d = 0.30$

End Of Calculation of Shear Capacity for element: column CC1 of floor 1
At local axis: 2
Integration Section: (b)

Calculation No. 14

column C1, Floor 1

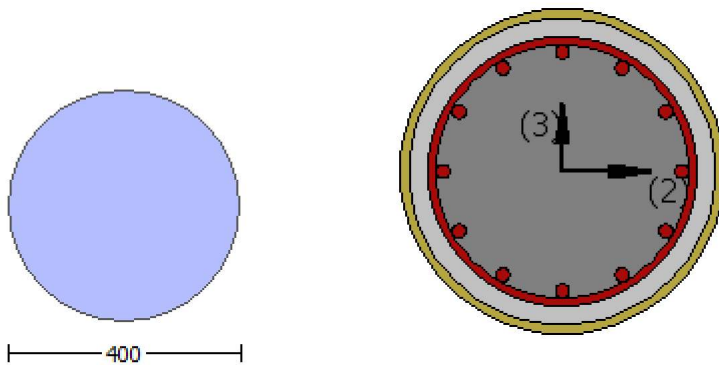
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

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, $\gamma = 0.85$

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.84055

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$

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: 3
EDGE -A-
Shear Force, $V_a = -3.7968243E-031$
EDGE -B-
Shear Force, $V_b = 3.7968243E-031$
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: $As_{l,ten} = 1017.876$
-Compression: $As_{l,com} = 1017.876$
-Middle: $As_{l,mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.27402927$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96425.251$
with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 1.4464E+008$
 $\mu_{u1+} = 1.4464E+008$, 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
 $\mu_{u1-} = 1.4464E+008$, 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
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 1.4464E+008$
 $\mu_{u2+} = 1.4464E+008$, 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
 $\mu_{u2-} = 1.4464E+008$, 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
 $\mu_u = 1.4464E+008$

$\phi = 0.9250245$
 $\phi' = 0.82105152$
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: $f_{cc} = f_c^* \quad c = 36.81095$
conf. factor $c = 1.84055$
 $f_c = 20.00$
From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \min(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $\phi' = \phi \cdot \min(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_{u1} -

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ_u
 $\mu_u = 1.4464E+008$

$$= 0.9250245$$

$$' = 0.82105152$$

error of function (3.68), Biskinis Phd = 31682.903

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 36.81095$

conf. factor $c = 1.84055$

$$f_c = 20.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$

$$l_b/d = 0.30$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00155946$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_{u2+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ_u
 $\mu_u = 1.4464E+008$

$$= 0.9250245$$

$$' = 0.82105152$$

error of function (3.68), Biskinis Phd = 31682.903

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 36.81095$

conf. factor $c = 1.84055$

$$f_c = 20.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$

$$l_b/d = 0.30$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00155946$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_{u2-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 1.4464\text{E}+008$

$\lambda = 0.9250245$
 $\lambda' = 0.82105152$
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: $f_{cc} = f_c' \cdot \lambda = 36.81095$
conf. factor $\lambda = 1.84055$
 $f_c = 20.00$
From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $\lambda = \lambda' \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 351879.387$

Calculation of Shear Strength at edge 1, $V_{r1} = 351879.387$

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

$V_{Col0} = 351879.387$

$k_{nl} = 1$ (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)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu = 9.8466009\text{E}-012$
 $V_u = 3.7968243\text{E}-031$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
From (11.5.4.8), ACI 318-14: $V_s = 175459.634$
 $A_v = \lambda/2 \cdot A_{stirrup} = 123370.055$
 $f_y = 444.4444$
 $s = 100.00$
 V_s is multiplied by $\lambda_{Col} = 0.00$
 $s/d = 0.3125$
 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: $\theta_1 = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \alpha_1)|)$, 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), 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: $V_s + V_f \leq 238930.50$
 $b_w d = \frac{A_s f_y}{4} = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 351879.387$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = k_n l V_{Col0}$
 $V_{Col0} = 351879.387$
 $k_n l = 1$ (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).

$k_n = 1$ (normal-weight concrete)
 $f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 9.8466009E-012$
 $\nu_u = 3.7968243E-031$
 $d = 0.8D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 175459.634$
 $A_v = \frac{A_s}{2} = 123370.055$
 $f_y = 444.4444$
 $s = 100.00$
 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 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: $\theta_1 = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L t / N_{Dir} = 1.016$
 $d_{fv} = d$ (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: $V_s + V_f \leq 238930.50$
 $b_w d = \frac{A_s f_y}{4} = 80424.772$

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, $\phi = 0.85$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####

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

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.84055

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$

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, $V_a = 4.4296389E-033$

EDGE -B-

Shear Force, $V_b = -4.4296389E-033$

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 , $V_e/V_r = 0.27402927$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96425.251$

with

$M_{pr1} = \text{Max}(\mu_{u1+} , \mu_{u1-}) = 1.4464E+008$

$\mu_{u1+} = 1.4464E+008$, 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

$\mu_{u1-} = 1.4464E+008$, 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

$M_{pr2} = \text{Max}(\mu_{u2+} , \mu_{u2-}) = 1.4464E+008$

$\mu_{u2+} = 1.4464E+008$, 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

$\mu_{u2-} = 1.4464E+008$, 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+}

95

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

= 0.9250245
' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: fcc = fc* c = 36.81095
conf. factor c = 1.84055
fc = 20.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 311.2087
lb/d = 0.30
d1 = 44.00
R = 200.00
v = 0.00155946
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.31060654

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

= 0.9250245
' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: fcc = fc* c = 36.81095
conf. factor c = 1.84055
fc = 20.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 311.2087
lb/d = 0.30
d1 = 44.00
R = 200.00
v = 0.00155946
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.31060654

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

= 0.9250245
' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: fcc = fc* c = 36.81095
conf. factor c = 1.84055
fc = 20.00

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$

$$l_b/d = 0.30$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00155946$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_2 -

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

$$\mu = 1.4464 \times 10^8$$

$$= 0.9250245$$

$$\gamma = 0.82105152$$

error of function (3.68), Biskinis Phd = 31682.903

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 36.81095$

$$\text{conf. factor } c = 1.84055$$

$$f_c = 20.00$$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$

$$l_b/d = 0.30$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00155946$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 351879.387$

Calculation of Shear Strength at edge 1, $V_{r1} = 351879.387$

$$V_{r1} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = k_n l \cdot V_{CoI0}$$

$$V_{CoI0} = 351879.387$$

$$k_n l = 1 \text{ (zero step-static loading)}$$

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).

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

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

$$M/Vd = 2.00$$

$$\mu = 9.0356326 \times 10^{-12}$$

$$V_u = 4.4296389 \times 10^{-33}$$

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

$$N_u = 4771.233$$

$$A_g = 125663.706$$

From (11.5.4.8), ACI 318-14: $V_s = 175459.634$

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

$$f_y = 444.4444$$

$s = 100.00$
 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 $V_f(,)$, 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, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (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: $V_s + V_f \leq 238930.50$
 $b_w \cdot d = \cdot d \cdot d / 4 = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 351879.387$
 $V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = \text{knl} \cdot V_{\text{ColO}}$
 $V_{\text{ColO}} = 351879.387$
 $\text{knl} = 1$ (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).

$\gamma = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 9.0356326\text{E-}012$
 $\mu_u = 4.4296389\text{E-}033$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 175459.634$
 $A_v = \cdot / 2 \cdot A_{\text{stirrup}} = 123370.055$
 $f_y = 444.4444$
 $s = 100.00$
 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 $V_f(,)$, 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, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (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: $V_s + V_f \leq 238930.50$
 $b_w \cdot d = \cdot d \cdot d / 4 = 80424.772$

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: 2

Integration Section: (b)

Section Type: rccs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_b/l_d = 0.30$

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, $M = 2.1330954E-011$

Shear Force, $V_2 = 3472.529$

Shear Force, $V_3 = 1.7790009E-014$

Axial Force, $F = -4769.844$

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, $D_{bL} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \gamma \cdot u = 0.04306525$

$u = \gamma \cdot u + p = 0.050665$

- Calculation of γ -

$\gamma = (M_y \cdot L_s / 3) / E_{eff} = 0.008665 ((4.29), \text{Biskinis Phd})$

$M_y = 1.3732E+008$

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

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 7.9240E+012$

factor = 0.30
 $A_g = 125663.706$
 $f_c' = 20.00$
 $N = 4769.844$
 $E_c I_g = 2.6413E+013$

Calculation of Yielding Moment M_y

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

$M_y = \min(M_{y_ten}, M_{y_com}) = 1.3732E+008$
 $\gamma = 7.5716672E-006$
 $M_{y_ten} (8c) = 1.3732E+008$
 $\gamma_{ten} (7c) = 72.23344$
error of function (7c) = 0.00097593
 $M_{y_com} (8d) = 3.7493E+008$
 $\gamma_{com} (7d) = 69.91126$
error of function (7d) = 0.00301342
with ((10.1), ASCE 41-17) $\gamma_y = \min(\gamma_y, 1.25 \cdot \gamma_y \cdot (l_b/l_d)^{2/3}) = 0.00222222$
 $\epsilon_{co} = 0.002$
 $\alpha_l = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00157305$
 $N = 4769.844$
 $A_c = 125663.706$
((10.1), ASCE 41-17) $\gamma = \min(\gamma, 1.25 \cdot \gamma \cdot (l_b/l_d)^{2/3}) = 0.44758025$
with $f_c' ((12.3), ACI 440) = 24.12975$
 $f_c = 20.00$
 $f_l = 1.3173$
 $k = 1$
Effective FRP thickness, $t_f = N L \cdot t \cdot \cos(b_1) = 1.016$
 $\epsilon_{fe} ((12.5) \text{ and } (12.7)) = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

- Calculation of p -

From table 10-9: $p = 0.042$

with:

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

shear control ratio $V_y E / V_{col} O E = 0.27402927$

$d = 0.00$

$s = 0.00$

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

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

$d_c = D - 2 \cdot \text{cover}$ - 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.

$N_{UD} = 4769.844$

$A_g = 125663.706$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 444.4444$

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

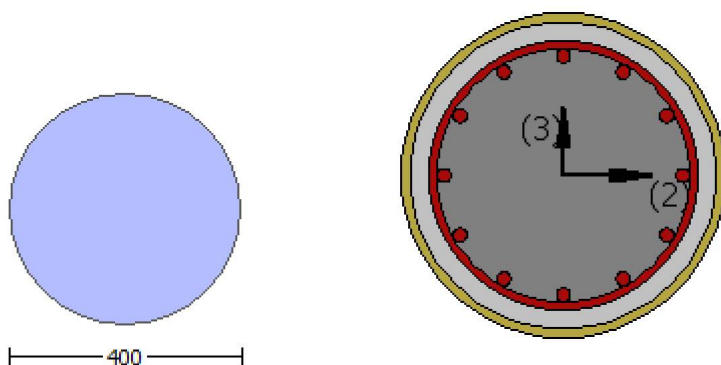
$f_{cE} = 20.00$

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 VRd
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, $\gamma = 0.85$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

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

Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Element Length, L = 3000.00
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou,min} = l_b/l_d = 0.30$
 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

EDGE -A-
 Bending Moment, $M_a = 3.1953177E-011$
 Shear Force, $V_a = -1.7790009E-014$
 EDGE -B-
 Bending Moment, $M_b = 2.1330954E-011$
 Shear Force, $V_b = 1.7790009E-014$
 BOTH EDGES
 Axial Force, F = -4769.844
 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, $D_{bL,ten} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = *V_n = 267605.553$
 V_n ((10.3), ASCE 41-17) = $k_n * V_{CoI} = 314830.062$
 $V_{CoI} = 314830.062$
 $k_n = 1.00$
 displacement_ductility_demand = 0.00

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)
 $f_c' = 16.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 2.1330954E-011$
 $V_u = 1.7790009E-014$
 $d = 0.8 * D = 320.00$
 $N_u = 4769.844$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 157913.67$
 $A_v = /2 * A_{stirrup} = 123370.055$
 $f_y = 400.00$
 $s = 100.00$
 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 $Vf(\theta)$, 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: $\theta = b1 + 90^\circ = 90.00$

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

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

$dfv = d$ (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: $Vs + Vf \leq 213705.936$

$bw * d = \frac{1}{4} * d * d = 80424.772$

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 $\theta = 3.2736361E-022$

$y = (My * Ls / 3) / Eleff = 0.008665$ ((4.29), Biskinis Phd))

$My = 1.3732E+008$

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

From table 10.5, ASCE 41_17: $Eleff = \text{factor} * Ec * Ig = 7.9240E+012$

factor = 0.30

$Ag = 125663.706$

$fc' = 20.00$

$N = 4769.844$

$Ec * Ig = 2.6413E+013$

Calculation of Yielding Moment My

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

$My = \text{Min}(My_{ten}, My_{com}) = 1.3732E+008$

$y = 7.5716672E-006$

My_{ten} (8c) = 1.3732E+008

$_{ten}$ (7c) = 72.23344

error of function (7c) = 0.00097593

My_{com} (8d) = 3.7493E+008

$_{com}$ (7d) = 69.91126

error of function (7d) = 0.00301342

with ((10.1), ASCE 41-17) $ey = \text{Min}(ey, 1.25 * ey * (lb / ld)^{2/3}) = 0.00222222$

$eco = 0.002$

$apl = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)

$d1 = 44.00$

$R = 200.00$

$v = 0.00157305$

$N = 4769.844$

$Ac = 125663.706$

((10.1), ASCE 41-17) $= \text{Min}(\frac{1}{4}, 1.25 * \frac{1}{4} * (lb / ld)^{2/3}) = 0.44758025$

with $fc' = 20.00$ ((12.3), ACI 440) = 24.12975

$fc = 20.00$

$fl = 1.3173$

$k = 1$

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

efe ((12.5) and (12.7)) = 0.004

$fu = 0.01$

$Ef = 64828.00$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

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

At local axis: 3

Integration Section: (b)

Calculation No. 16

column C1, Floor 1

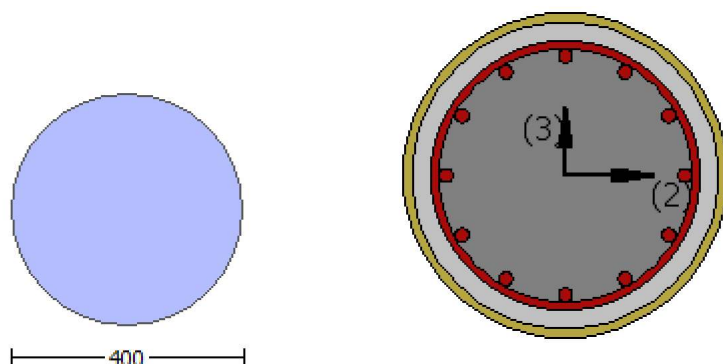
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

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, $\gamma = 0.85$

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

Diameter, $D = 400.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.84055
 Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{o,min} = 0.30$
 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, $N_{oDir} = 1$
 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, $V_a = -3.7968243E-031$
 EDGE -B-
 Shear Force, $V_b = 3.7968243E-031$
 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 , $V_e/V_r = 0.27402927$
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96425.251$
 with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 1.4464E+008$
 $\mu_{u1+} = 1.4464E+008$, 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
 $\mu_{u1-} = 1.4464E+008$, 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
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 1.4464E+008$
 $\mu_{u2+} = 1.4464E+008$, 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
 $\mu_{u2-} = 1.4464E+008$, 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
 $\mu_u = 1.4464E+008$
 $= 0.9250245$

' = 0.82105152
 error of function (3.68), Biskinis Phd = 31682.903
 From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 36.81095$
 conf. factor $c = 1.84055$
 $f_c = 20.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_{1-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 1.4464\text{E}+008$

= 0.9250245
 ' = 0.82105152
 error of function (3.68), Biskinis Phd = 31682.903
 From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 36.81095$
 conf. factor $c = 1.84055$
 $f_c = 20.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_{2+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 1.4464\text{E}+008$

= 0.9250245
 ' = 0.82105152
 error of function (3.68), Biskinis Phd = 31682.903
 From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 36.81095$
 conf. factor $c = 1.84055$
 $f_c = 20.00$
 From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$

$$v = 0.00155946$$

$$N = 4771.233$$

$$Ac = 125663.706$$

$$= *Min(1, 1.25*(lb/d)^{2/3}) = 0.31060654$$

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

$$= 0.9250245$$

$$' = 0.82105152$$

error of function (3.68), Biskinis Phd = 31682.903

From 5A.2, TBDY: $f_{cc} = f_c' \cdot c = 36.81095$

conf. factor $c = 1.84055$

$f_c = 20.00$

From 10.3.5, ASCE41-17, Final value of f_y : $f_y * Min(1, 1.25*(lb/d)^{2/3}) = 311.2087$

lb/d = 0.30

d1 = 44.00

R = 200.00

v = 0.00155946

N = 4771.233

Ac = 125663.706

$$= *Min(1, 1.25*(lb/d)^{2/3}) = 0.31060654$$

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Shear Strength $V_r = Min(V_{r1}, V_{r2}) = 351879.387$

Calculation of Shear Strength at edge 1, $V_{r1} = 351879.387$

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

$V_{Col0} = 351879.387$

$k_n I = 1$ (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).

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

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

$M/Vd = 2.00$

$$Mu = 9.8466009E-012$$

$$Vu = 3.7968243E-031$$

d = $0.8 * D = 320.00$

Nu = 4771.233

Ag = 125663.706

From (11.5.4.8), ACI 318-14: $V_s = 175459.634$

$A_v = /2 * A_{stirrup} = 123370.055$

$f_y = 444.4444$

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 $V_f(\theta)$, 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, $tf1 = NL * t / NoDir = 1.016$
 $dfv = d$ (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: $V_s + V_f \leq 238930.50$
 $bw * d = \rho * d * d / 4 = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 351879.387$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $knl * V_{Col0}$
 $V_{Col0} = 351879.387$
 $knl = 1$ (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)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M / Vd = 2.00$
 $\mu_u = 9.8466009E-012$
 $\mu_v = 3.7968243E-031$
 $d = 0.8 * D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
 From (11.5.4.8), ACI 318-14: $V_s = 175459.634$
 $A_v = \rho / 2 * A_{stirrup} = 123370.055$
 $f_y = 444.4444$
 $s = 100.00$
 V_s is multiplied by $\rho_{Col} = 0.00$
 $s/d = 0.3125$
 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 $V_f(\theta)$, 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, $tf1 = NL * t / NoDir = 1.016$
 $dfv = d$ (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: $V_s + V_f \leq 238930.50$
 $bw * d = \rho * d * d / 4 = 80424.772$

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, $\phi = 0.85$

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

Diameter, $D = 400.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.84055

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$

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

At local axis: 2

EDGE -A-

Shear Force, $V_a = 4.4296389E-033$

EDGE -B-

Shear Force, $V_b = -4.4296389E-033$

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, $V_e/V_r = 0.27402927$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96425.251$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.4464E+008$

$Mu_{1+} = 1.4464E+008$, 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

Mu1- = 1.4464E+008, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
Mpr2 = Max(Mu2+ , Mu2-) = 1.4464E+008
Mu2+ = 1.4464E+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
Mu2- = 1.4464E+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 Mu1+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

= 0.9250245
' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: fcc = fc* c = 36.81095
conf. factor c = 1.84055
fc = 20.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 311.2087
lb/d = 0.30
d1 = 44.00
R = 200.00
v = 0.00155946
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.31060654

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 1.4464E+008

= 0.9250245
' = 0.82105152
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TBDY: fcc = fc* c = 36.81095
conf. factor c = 1.84055
fc = 20.00
From 10.3.5, ASCE41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 311.2087
lb/d = 0.30
d1 = 44.00
R = 200.00
v = 0.00155946
N = 4771.233
Ac = 125663.706
= *Min(1,1.25*(lb/d)^ 2/3) = 0.31060654

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of μ_{2+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 1.4464E+008$

$\phi = 0.9250245$
 $\lambda = 0.82105152$
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TB DY: $f_{cc} = f_c \cdot c = 36.81095$
conf. factor $c = 1.84055$
 $f_c = 20.00$
From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of μ_{2-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 1.4464E+008$

$\phi = 0.9250245$
 $\lambda = 0.82105152$
error of function (3.68), Biskinis Phd = 31682.903
From 5A.2, TB DY: $f_{cc} = f_c \cdot c = 36.81095$
conf. factor $c = 1.84055$
 $f_c = 20.00$
From 10.3.5, ASCE41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 311.2087$
 $l_b/d = 0.30$
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00155946$
 $N = 4771.233$
 $A_c = 125663.706$
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.31060654$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 351879.387$

Calculation of Shear Strength at edge 1, $V_{r1} = 351879.387$
 $V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l \cdot V_{Col0}$
 $V_{Col0} = 351879.387$
 $k_n = 1$ (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).

$= 1$ (normal-weight concrete)
 $f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 9.0356326E-012$
 $\nu_u = 4.4296389E-033$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
From (11.5.4.8), ACI 318-14: $V_s = 175459.634$
 $A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 123370.055$
 $f_y = 444.4444$
 $s = 100.00$
 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: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, 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), 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: $V_s + V_f \leq 238930.50$
 $b_w \cdot d = \sqrt{4} \cdot d = 80424.772$

Calculation of Shear Strength at edge 2, $V_{r2} = 351879.387$

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

$V_{\text{Col}0} = 351879.387$

$k_{nl} = 1$ (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)
 $f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 9.0356326E-012$
 $\nu_u = 4.4296389E-033$
 $d = 0.8 \cdot D = 320.00$
 $N_u = 4771.233$
 $A_g = 125663.706$
From (11.5.4.8), ACI 318-14: $V_s = 175459.634$
 $A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 123370.055$
 $f_y = 444.4444$
 $s = 100.00$
 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: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

dfv = 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 <= 238930.50
bw*d = *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: 3
Integration Section: (b)
Section Type: rccs

Constant Properties

Knowledge Factor, = 0.85
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Primary Member: Concrete Strength, fc = fcm = 20.00
Existing material of Primary Member: Steel Strength, fs = fsm = 444.4444
Concrete Elasticity, Ec = 21019.039
Steel Elasticity, Es = 200000.00
Diameter, D = 400.00
Cover Thickness, c = 25.00
Element Length, L = 3000.00
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with lb/ld = 0.30
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

Bending Moment, M = 0.09482631
Shear Force, V2 = 3472.529
Shear Force, V3 = 1.7790009E-014
Axial Force, F = -4769.844
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 3053.628
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

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = u = 0.03717305$
 $u = y + p = 0.043733$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.001733$ ((4.29), Biskinis Phd))
 $M_y = 1.3732E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 7.9240E+012$
 $factor = 0.30$
 $A_g = 125663.706$
 $f_c' = 20.00$
 $N = 4769.844$
 $E_c * I_g = 2.6413E+013$

Calculation of Yielding Moment M_y

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

$M_y = \min(M_{y_ten}, M_{y_com}) = 1.3732E+008$
 $y = 7.5716672E-006$
 M_{y_ten} (8c) = $1.3732E+008$
 $_{ten}$ (7c) = 72.23344
error of function (7c) = 0.00097593
 M_{y_com} (8d) = $3.7493E+008$
 $_{com}$ (7d) = 69.91126
error of function (7d) = 0.00301342
with ((10.1), ASCE 41-17) $e_y = \min(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.00222222$
 $e_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 200.00$
 $v = 0.00157305$
 $N = 4769.844$
 $A_c = 125663.706$
((10.1), ASCE 41-17) $= \min(, 1.25 * (l_b / l_d)^{2/3}) = 0.44758025$
with $f_c' ((12.3), ACI 440) = 24.12975$
 $f_c = 20.00$
 $f_l = 1.3173$
 $k = 1$
Effective FRP thickness, $t_f = N L * t * \cos(b_1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $f_u = 0.01$
 $E_f = 64828.00$

Calculation of ratio l_b / l_d

Inadequate Lap Length with $l_b / l_d = 0.30$

- Calculation of p -

From table 10-9: $p = 0.042$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b / l_d \geq 1$
shear control ratio $V_y E / V_{col} E = 0.27402927$
 $d = 0.00$
 $s = 0.00$
 $t = 2 * A_v / (d c * s) + 4 * t_f / D * (f_{fe} / f_s) = 0.00$

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

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

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.

$N_{UD} = 4769.844$

$A_g = 125663.706$

$f_{cE} = 20.00$

$f_{yE} = f_{yI} = 444.4444$

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

$f_{cE} = 20.00$

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

At local axis: 3

Integration Section: (b)
