

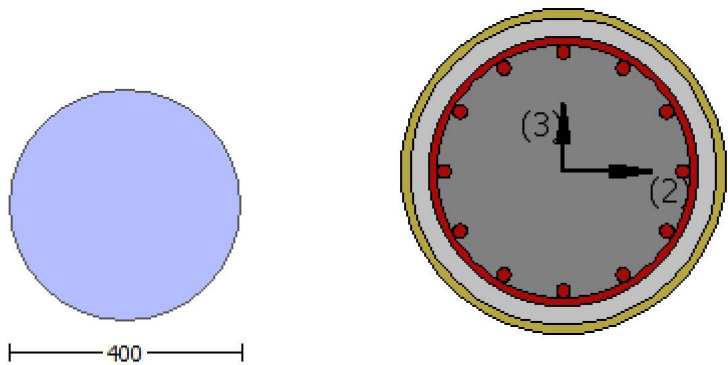
# Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

## Calculation No. 1

column C1, Floor 1  
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)  
Analysis: Uniform +X  
Check: Shear capacity VRd  
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,  $\gamma = 1.00$   
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.  
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 420.00$   
Concrete Elasticity,  $E_c = 23025.204$

Steel Elasticity,  $E_s = 200000.00$   
 #####  
 Note: Especially for the calculation of  $\gamma$  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,  $f_c = f_{cm} = 24.00$   
 Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$   
 #####  
 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  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_o/l_{ou,min} = l_b/l_d \geq 1$ )  
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $e_{fu} = 0.01$   
 Number of directions,  $NoDir = 1$   
 Fiber orientations,  $bi: 0.00^\circ$   
 Number of layers,  $NL = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

EDGE -A-  
 Bending Moment,  $M_a = -1.0733E+007$   
 Shear Force,  $V_a = -3575.956$   
 EDGE -B-  
 Bending Moment,  $M_b = 0.09489048$   
 Shear Force,  $V_b = 3575.956$   
 BOTH EDGES  
 Axial Force,  $F = -4769.80$   
 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  $V_R = V_n = 264267.995$   
 $V_n ((10.3), ASCE 41-17) = knl * V_{CoIO} = 264267.995$   
 $V_{CoI} = 264267.995$   
 $knl = 1.00$   
 $displacement\_ductility\_demand = 0.01013255$

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).

$\gamma = 1$  (normal-weight concrete)  
 $f'_c = 16.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $M_u = 1.0733E+007$   
 $V_u = 3575.956$   
 $d = 0.8 * D = 320.00$

$N_u = 4769.80$   
 $A_g = 125663.706$   
 From (11.5.4.8), ACI 318-14:  $V_s = 165809.354$   
 $A_v = \frac{1}{2} A_{stirrup} = 123370.055$   
 $f_y = 420.00$   
 $s = 100.00$   
 $V_s$  is multiplied by  $\text{Col} = 0.00$   
 $s/d = 0.3125$   
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 194961.134$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L * t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 370.00  
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 213705.936$   
 $b_w * d = \frac{V_s * d}{4} = 80424.772$

displacement ductility demand is calculated as  $\delta / y$

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

From analysis, chord rotation  $\theta = 0.00033407$   
 $y = (M_y * L_s / 3) / E_{eff} = 0.03297001$  ((4.29), Biskinis Phd))  
 $M_y = 2.8606E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3001.332  
 From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} * E_c * I_g = 8.6803E+012$   
 $\text{factor} = 0.30$   
 $A_g = 125663.706$   
 $f_c' = 24.00$   
 $N = 4769.80$   
 $E_c * I_g = 2.8934E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta$  and  $M_y$  according to (7) - (8) in Biskinis and Fardis

$M_y = \text{Min}(M_{y\_ten}, M_{y\_com}) = 2.8606E+008$   
 $y$  ((10a) or (10b)) = 1.6206346E-005  
 $M_{y\_ten}$  (8a) = 2.8606E+008  
 $\delta_{ten}$  (7a) = 73.23937  
 error of function (7a) = 0.00140751  
 $M_{y\_com}$  (8b) = 4.0293E+008  
 $\delta_{com}$  (7b) = 68.98129  
 error of function (7b) = -0.00043134  
 with  $e_y = 0.002625$   
 $e_{co} = 0.002$   
 $a_{pl} = 0.45$  ((9c) in Biskinis and Fardis for FRP Wrap)  
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00134935$   
 $N = 4769.80$   
 $A_c = 125663.706$   
 $= 0.45352339$

with  $f_c^*$  ((12.3), ACI 440) = 28.12975  
 $f_c = 24.00$   
 $f_l = 1.3173$   
 $k = 1$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(\theta_1) = 1.016$   
 $e_{fe}$  ((12.5) and (12.7)) = 0.004  
 $E_f = 64828.00$

Calculation of ratio  $I_b/I_d$

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

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

At local axis: 2

Integration Section: (a)

## Calculation No. 2

column C1, Floor 1

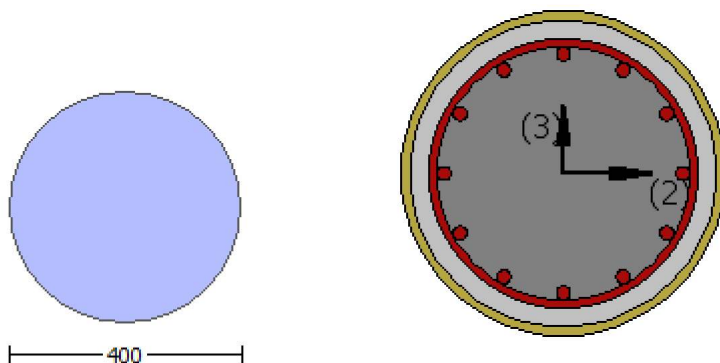
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

Edge: Start

Local Axis: (2)



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

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rccs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

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Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$ 
Concrete Elasticity,  $E_c = 23025.204$ 
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,  $f_s = 1.25 \cdot f_{sm} = 656.25$ 
#####
Diameter,  $D = 400.00$ 
Cover Thickness,  $c = 25.00$ 
Mean Confinement Factor overall section = 1.72976
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
Adequate Lap Length ( $l_o/l_{ou}, \min \geq 1$ )
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $\epsilon_{fu} = 0.01$ 
Number of directions,  $N_{oDir} = 1$ 
Fiber orientations,  $b_i: 0.00^\circ$ 
Number of layers,  $N_L = 1$ 
Radius of rounding corners,  $R = 40.00$ 
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Stepwise Properties
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At local axis: 3
EDGE -A-
Shear Force,  $V_a = -2.2164346E-030$ 
EDGE -B-
Shear Force,  $V_b = 2.2164346E-030$ 
BOTH EDGES
Axial Force,  $F = -4771.233$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
  -Tension:  $A_{slt} = 0.00$ 
  -Compression:  $A_{slc} = 3053.628$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
  -Tension:  $A_{sl,ten} = 1017.876$ 
  -Compression:  $A_{sl,com} = 1017.876$ 
  -Middle:  $A_{sl,mid} = 1017.876$ 
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Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.48361756$ 
Member Controlled by Flexure ( $V_e/V_r < 1$ )
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 186373.736$ 
with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 2.7956E+008$ 
 $\mu_{u1+} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $\mu_{u1-} = 2.7956E+008$ , 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
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 2.7956E+008$ 
 $\mu_{u2+} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the the static loading combination
 $\mu_{u2-} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment
direction which is defined for the the static loading combination
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Calculation of Mu1+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465  
' = 0.94240061  
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY: fcc = fc\* c = 41.51419  
conf. factor c = 1.72976  
fc = 24.00  
From 10.3.5, ASCE41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 656.25  
lb/d = 1.00  
d1 = 44.00  
R = 200.00  
v = 0.00133941  
N = 4771.233  
Ac = 125663.706  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.56255742

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465  
' = 0.94240061  
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY: fcc = fc\* c = 41.51419  
conf. factor c = 1.72976  
fc = 24.00  
From 10.3.5, ASCE41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 656.25  
lb/d = 1.00  
d1 = 44.00  
R = 200.00  
v = 0.00133941  
N = 4771.233  
Ac = 125663.706  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.56255742

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465  
' = 0.94240061

error of function (3.68), Biskinis Phd = 47223.857  
 From 5A.2, TBDY:  $f_{cc} = f_c' \cdot c = 41.51419$   
 conf. factor  $c = 1.72976$   
 $f_c = 24.00$   
 From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $A_c = 125663.706$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_2$ -

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.7956E+008$

$= 1.06465$   
 $' = 0.94240061$   
 error of function (3.68), Biskinis Phd = 47223.857  
 From 5A.2, TBDY:  $f_{cc} = f_c' \cdot c = 41.51419$   
 conf. factor  $c = 1.72976$   
 $f_c = 24.00$   
 From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $A_c = 125663.706$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 385374.211$

Calculation of Shear Strength at edge 1,  $V_{r1} = 385374.211$   
 $V_{r1} = V_{CoI} \cdot ((10.3), ASCE 41-17) = k_{nl} \cdot V_{CoIO}$   
 $V_{CoIO} = 385374.211$   
 $k_{nl} = 1$  (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)  
 $f_c' = 24.00$ , but  $f_c'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu = 1.4753320E-011$   
 $V_u = 2.2164346E-030$   
 $d = 0.8 \cdot D = 320.00$   
 $N_u = 4771.233$

$A_g = 125663.706$   
 From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$   
 $A_v = \frac{1}{2} A_{stirrup} = 123370.055$   
 $f_y = 525.00$   
 $s = 100.00$   
 $V_s$  is multiplied by  $\text{Col} = 0.00$   
 $s/d = 0.3125$   
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 194961.134$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 370.00  
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 261735.249$   
 $b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 80424.772$

Calculation of Shear Strength at edge 2,  $V_{r2} = 385374.211$   
 $V_{r2} = V_{Col} ((10.3), \text{ASCE } 41-17) = k_{nl} \cdot V_{Col0}$   
 $V_{Col0} = 385374.211$   
 $k_{nl} = 1$  (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).

$\theta = 1$  (normal-weight concrete)  
 $f'_c = 24.00$ , but  $f'_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.4753320\text{E-}011$   
 $V_u = 2.2164346\text{E-}030$   
 $d = 0.8 \cdot D = 320.00$   
 $N_u = 4771.233$   
 $A_g = 125663.706$   
 From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$   
 $A_v = \frac{1}{2} A_{stirrup} = 123370.055$   
 $f_y = 525.00$   
 $s = 100.00$   
 $V_s$  is multiplied by  $\text{Col} = 0.00$   
 $s/d = 0.3125$   
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 194961.134$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 370.00  
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 261735.249$   
 $b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 80424.772$



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

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

#### Constant Properties

Knowledge Factor,  $\gamma = 1.00$   
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$   
Concrete Elasticity,  $E_c = 23025.204$   
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,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
#####  
Diameter,  $D = 400.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.72976  
Element Length,  $L = 3000.00$   
Primary Member  
Smooth Bars  
Ductile Steel  
With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Adequate Lap Length ( $l_o/l_{ou}, \min \geq 1$ )  
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $\epsilon_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i: 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = 7.8886091E-031$   
EDGE -B-  
Shear Force,  $V_b = -7.8886091E-031$   
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 ,  $V_e/V_r = 0.48361756$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 186373.736$   
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 2.7956E+008$

$\mu_{1+} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{1-} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 2.7956E+008$

$\mu_{2+} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

-----  
Calculation of  $\mu_{1+}$   
-----

-----  
Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu_u$   
 $\mu_u = 2.7956E+008$   
-----

$\phi = 1.06465$

$\phi' = 0.94240061$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TB DY:  $f_{cc} = f_c^* \quad c = 41.51419$

conf. factor  $c = 1.72976$

$f_c = 24.00$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 200.00$

$v = 0.00133941$

$N = 4771.233$

$A_c = 125663.706$

$= \phi \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$   
-----

Calculation of ratio  $l_b/d$   
-----

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

Calculation of  $\mu_{1-}$   
-----

-----  
Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu_u$   
 $\mu_u = 2.7956E+008$   
-----

$\phi = 1.06465$

$\phi' = 0.94240061$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TB DY:  $f_{cc} = f_c^* \quad c = 41.51419$

conf. factor  $c = 1.72976$

$f_c = 24.00$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 200.00$

$v = 0.00133941$

$N = 4771.233$

$A_c = 125663.706$

$= \phi \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_{2+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.7956E+008$

$$= 1.06465$$

$$' = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$

conf. factor  $c = 1.72976$

$$f_c = 24.00$$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00133941$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_{2-}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.7956E+008$

$$= 1.06465$$

$$' = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$

conf. factor  $c = 1.72976$

$$f_c = 24.00$$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00133941$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 385374.211$

Calculation of Shear Strength at edge 1,  $V_{r1} = 385374.211$

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

$V_{Col0} = 385374.211$

$k_{nl} = 1$  (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)

$f_c' = 24.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 7.3565446E-012$

$V_u = 7.8886091E-031$

$d = 0.8 * D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$

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

$f_y = 525.00$

$s = 100.00$

$V_s$  is multiplied by  $Col = 0.00$

$s/d = 0.3125$

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

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

$V_f = \min(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:

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

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

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 261735.249$

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

Calculation of Shear Strength at edge 2,  $V_{r2} = 385374.211$

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

$V_{Col0} = 385374.211$

$k_{nl} = 1$  (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)

$f_c' = 24.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 7.3565446E-012$

$V_u = 7.8886091E-031$

$d = 0.8 * D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$

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

$f_y = 525.00$

$s = 100.00$

$V_s$  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

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), 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:  $V_s + V_f \leq 261735.249$

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

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,  $\phi = 1.00$

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

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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,  $M = 8.1497328E-010$

Shear Force,  $V_2 = -3575.956$

Shear Force,  $V_3 = -2.9854277E-013$

Axial Force,  $F = -4769.80$

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  $u_R = \gamma + p = 0.02147769$   
 $u = \gamma + p = 0.02147769$

- Calculation of  $\gamma$  -

$\gamma = (M_y \cdot L_s / 3) / E_{eff} = 0.01647769$  ((4.29), Biskinis Phd))  
 $M_y = 2.8606E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 1500.00  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 8.6803E+012$   
 $factor = 0.30$   
 $A_g = 125663.706$   
 $f_c' = 24.00$   
 $N = 4769.80$   
 $E_c \cdot I_g = 2.8934E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $\gamma$  and  $M_y$  according to (7) - (8) in Biskinis and Fardis

$M_y = \min(M_{y\_ten}, M_{y\_com}) = 2.8606E+008$   
 $\gamma$  ((10a) or (10b)) = 1.6206346E-005  
 $M_{y\_ten}$  (8a) = 2.8606E+008  
 $\gamma_{ten}$  (7a) = 73.23937  
 error of function (7a) = 0.00140751  
 $M_{y\_com}$  (8b) = 4.0293E+008  
 $\gamma_{com}$  (7b) = 68.98129  
 error of function (7b) = -0.00043134  
 with  $e_y = 0.002625$   
 $e_{co} = 0.002$   
 $a_{pl} = 0.45$  ((9c) in Biskinis and Fardis for FRP Wrap)  
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00134935$   
 $N = 4769.80$   
 $A_c = 125663.706$   
 $= 0.45352339$   
 with  $f_c^*$  ((12.3), ACI 440) = 28.12975  
 $f_c = 24.00$   
 $f_l = 1.3173$   
 $k = 1$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $e_f$  ((12.5) and (12.7)) = 0.004  
 $E_f = 64828.00$

Calculation of ratio  $l_b/d$

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

- Calculation of  $p$  -

From table 10-9:  $p = 0.005$

with:

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

shear control ratio  $V_{yE}/V_{ColOE} = 0.48361756$

$d = 0.00$

$s = 0.00$

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

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

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

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

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

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

$N_{UD} = 4769.80$

$A_g = 125663.706$

$f_{cE} = 24.00$

$f_{ytE} = f_{ylE} = 525.00$

$\rho_l = \text{Area\_Tot\_Long\_Rein} / (A_g) = 0.0243$

$f_{cE} = 24.00$

-----  
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

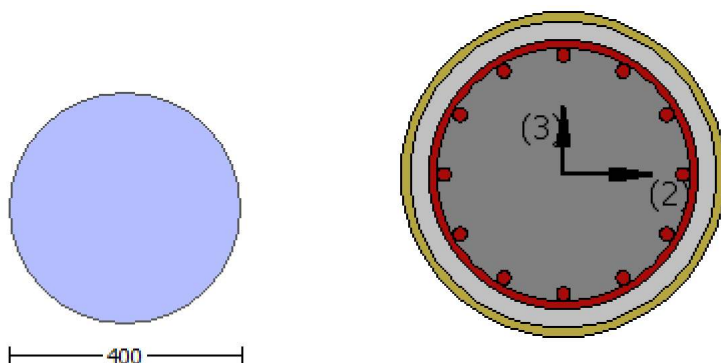
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

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,  $\gamma = 1.00$   
 Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.  
 Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17  
 Consequently:  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 420.00$   
 Concrete Elasticity,  $E_c = 23025.204$   
 Steel Elasticity,  $E_s = 200000.00$   
 #####  
 Note: Especially for the calculation of  $\gamma$  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,  $f_c = f_{cm} = 24.00$   
 Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$   
 #####  
 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  
 Adequate Lap Length ( $l_o/l_{ou,min} = l_b/d \geq 1$ )  
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $\epsilon_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i: 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

EDGE -A-  
 Bending Moment,  $M_a = 8.1497328E-010$   
 Shear Force,  $V_a = -2.9854277E-013$   
 EDGE -B-  
 Bending Moment,  $M_b = 8.1069813E-011$   
 Shear Force,  $V_b = 2.9854277E-013$   
 BOTH EDGES  
 Axial Force,  $F = -4769.80$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{sl,t} = 1272.345$   
   -Compression:  $A_{sl,c} = 1781.283$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{sl,ten} = 1017.876$   
   -Compression:  $A_{sl,com} = 1017.876$   
   -Middle:  $A_{sl,mid} = 1017.876$   
 Mean Diameter of Tension Reinforcement,  $D_{bL,ten} = 18.00$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = \phi V_n = 314830.054$   
 $V_n ((10.3), ASCE 41-17) = k_n l^* V_{CoI0} = 314830.054$   
 $V_{CoI} = 314830.054$   
 $k_n l = 1.00$   
 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  $f'_c \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 8.1497328E-010$

$V_u = 2.9854277E-013$

$d = 0.8 \cdot D = 320.00$

$N_u = 4769.80$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14:  $V_s = 165809.354$

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

$f_y = 420.00$

$s = 100.00$

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

$s/d = 0.3125$

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

$f = 0.95$ , for fully-wrapped sections

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

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

This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $\theta_i$ , 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,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$  (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:  $V_s + V_f \leq 213705.936$

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

displacement\_ductility\_demand is calculated as  $\delta / y$

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

From analysis, chord rotation  $\theta = 2.9082068E-020$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.01647769$  ((4.29), Biskinis Phd))

$M_y = 2.8606E+008$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 8.6803E+012$

factor = 0.30

$A_g = 125663.706$

$f'_c = 24.00$

$N = 4769.80$

$E_c \cdot I_g = 2.8934E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta$  and  $M_y$  according to (7) - (8) in Biskinis and Fardis

$M_y = \text{Min}(M_{y\_ten}, M_{y\_com}) = 2.8606E+008$

$y$  ((10a) or (10b)) = 1.6206346E-005

$M_{y\_ten}$  (8a) = 2.8606E+008

$\delta_{ten}$  (7a) = 73.23937

error of function (7a) = 0.00140751

$M_{y\_com}$  (8b) = 4.0293E+008

$\delta_{com}$  (7b) = 68.98129

error of function (7b) = -0.00043134

with  $e_y = 0.002625$

$\epsilon_{co} = 0.002$   
 $\alpha_{pl} = 0.45$  ((9c) in Biskinis and Fardis for FRP Wrap)  
 $d_1 = 44.00$   
 $R = 200.00$   
 $\nu = 0.00134935$   
 $N = 4769.80$   
 $A_c = 125663.706$   
 $= 0.45352339$   
 with  $f_c^*$  ((12.3), ACI 440) = 28.12975  
 $f_c = 24.00$   
 $f_l = 1.3173$   
 $k = 1$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $\epsilon_{fe}$  ((12.5) and (12.7)) = 0.004  
 $E_f = 64828.00$

Calculation of ratio  $l_b/d$

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

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

At local axis: 3

Integration Section: (a)

## Calculation No. 4

column C1, Floor 1

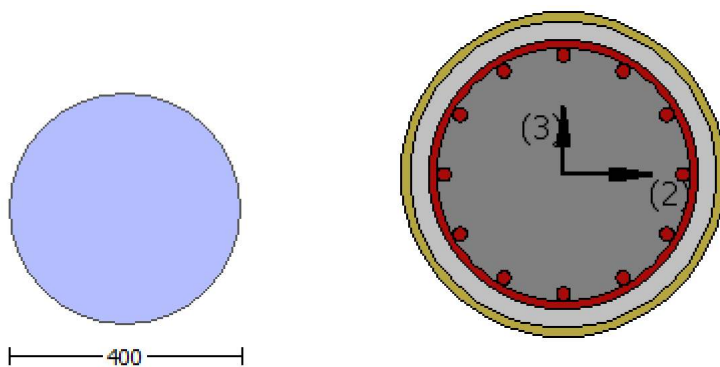
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\phi$ )

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,  $\gamma = 1.00$

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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,  $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Diameter,  $D = 400.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.72976

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

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

### Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = -2.2164346E-030$

EDGE -B-

Shear Force,  $V_b = 2.2164346E-030$

BOTH EDGES

Axial Force,  $F = -4771.233$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $A_{sc} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.48361756$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 186373.736$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.7956E+008$

$M_{u1+} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment

direction which is defined for the static loading combination

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.7956E+008$$

$M_{u2+} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 2.7956E+008$ , 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),  $M_u$   
 $M_u = 2.7956E+008$

$$= 1.06465$$

$$' = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TDY:  $f_{cc} = f_c \cdot c = 41.51419$

conf. factor  $c = 1.72976$

$$f_c = 24.00$$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00133941$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of  $M_{u1-}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $M_u$   
 $M_u = 2.7956E+008$

$$= 1.06465$$

$$' = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TDY:  $f_{cc} = f_c \cdot c = 41.51419$

conf. factor  $c = 1.72976$

$$f_c = 24.00$$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00133941$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of  $M_{u2+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465  
' = 0.94240061  
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY: fcc = fc\* c = 41.51419  
conf. factor c = 1.72976  
fc = 24.00  
From 10.3.5, ASCE41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 656.25  
lb/d = 1.00  
d1 = 44.00  
R = 200.00  
v = 0.00133941  
N = 4771.233  
Ac = 125663.706  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.56255742

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465  
' = 0.94240061  
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY: fcc = fc\* c = 41.51419  
conf. factor c = 1.72976  
fc = 24.00  
From 10.3.5, ASCE41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 656.25  
lb/d = 1.00  
d1 = 44.00  
R = 200.00  
v = 0.00133941  
N = 4771.233  
Ac = 125663.706  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.56255742

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 385374.211

Calculation of Shear Strength at edge 1, Vr1 = 385374.211  
Vr1 = VCol ((10.3), ASCE 41-17) = knl\*VColO  
VColO = 385374.211  
knl = 1 (zero step-static loading)

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

$\lambda = 1$  (normal-weight concrete)  
 $f'_c = 24.00$ , but  $f'_c \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.4753320E-011$   
 $\mu_v = 2.2164346E-030$   
 $d = 0.8 \cdot D = 320.00$   
 $N_u = 4771.233$   
 $A_g = 125663.706$   
 From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$   
 $A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 123370.055$   
 $f_y = 525.00$   
 $s = 100.00$   
 $V_s$  is multiplied by  $\text{Col} = 0.00$   
 $s/d = 0.3125$   
 $V_f ((11-3)-(11.4), \text{ACI 440}) = 194961.134$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = 45^\circ$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 370.00  
 $f_{fe} ((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 261735.249$   
 $b_w \cdot d = \sqrt{4} \cdot d = 80424.772$

Calculation of Shear Strength at edge 2,  $V_{r2} = 385374.211$   
 $V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE 41-17}) = k_{nl} \cdot V_{\text{ColO}}$   
 $V_{\text{ColO}} = 385374.211$   
 $k_{nl} = 1$  (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)  
 $f'_c = 24.00$ , but  $f'_c \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.4753320E-011$   
 $\mu_v = 2.2164346E-030$   
 $d = 0.8 \cdot D = 320.00$   
 $N_u = 4771.233$   
 $A_g = 125663.706$   
 From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$   
 $A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 123370.055$   
 $f_y = 525.00$   
 $s = 100.00$   
 $V_s$  is multiplied by  $\text{Col} = 0.00$   
 $s/d = 0.3125$   
 $V_f ((11-3)-(11.4), \text{ACI 440}) = 194961.134$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = 45^\circ$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 370.00

```

ffe ((11-5), ACI 440) = 259.312
Ef = 64828.00
fe = 0.004, from (11.6a), ACI 440
with fu = 0.01
From (11-11), ACI 440: Vs + Vf <= 261735.249
bw*d = *d*d/4 = 80424.772
-----

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

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

Constant Properties
-----
Knowledge Factor, = 1.00
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, fc = fcm = 24.00
Existing material of Primary Member: Steel Strength, fs = fsm = 525.00
Concrete Elasticity, Ec = 23025.204
Steel Elasticity, Es = 200000.00
#####
Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, fs = 1.25*fsm = 656.25
#####
Diameter, D = 400.00
Cover Thickness, c = 25.00
Mean Confinement Factor overall section = 1.72976
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
Adequate Lap Length (lo/lou,min>=1)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, ffu = 1055.00
Tensile Modulus, Ef = 64828.00
Elongation, efu = 0.01
Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00
-----

Stepwise Properties
-----
At local axis: 2
EDGE -A-
Shear Force, Va = 7.8886091E-031
EDGE -B-
Shear Force, Vb = -7.8886091E-031
BOTH EDGES
Axial Force, F = -4771.233
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00

```

-Compression:  $A_{sc} = 3053.628$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{s,ten} = 1017.876$   
-Compression:  $A_{s,com} = 1017.876$   
-Middle:  $A_{s,mid} = 1017.876$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.48361756$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 186373.736$   
with

$M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 2.7956E+008$

$\mu_{u1+} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{u1-} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 2.7956E+008$

$\mu_{u2+} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{u2-} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $\mu_{u1+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu_u$   
 $\mu_u = 2.7956E+008$

$$= 1.06465$$

$$\lambda = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TB DY:  $f_{cc} = f_c^* \quad c = 41.51419$

conf. factor  $c = 1.72976$

$$f_c = 24.00$$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00133941$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \lambda \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_{u1-}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu_u$   
 $\mu_u = 2.7956E+008$

$$= 1.06465$$

$$\lambda = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TB DY:  $f_{cc} = f_c^* \quad c = 41.51419$

conf. factor  $c = 1.72976$

$$f_c = 24.00$$



From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00133941$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_{2+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$

$$\mu = 2.7956 \times 10^8$$

$$= 1.06465$$

$$' = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$

$$\text{conf. factor } c = 1.72976$$

$$f_c = 24.00$$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00133941$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_{2-}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$

$$\mu = 2.7956 \times 10^8$$

$$= 1.06465$$

$$' = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$

$$\text{conf. factor } c = 1.72976$$

$$f_c = 24.00$$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00133941$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 385374.211$

Calculation of Shear Strength at edge 1,  $V_{r1} = 385374.211$

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

$V_{Col0} = 385374.211$

$k_{nl} = 1$  (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)

$f'_c = 24.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 7.3565446E-012$

$\nu_u = 7.8886091E-031$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$

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

$f_y = 525.00$

$s = 100.00$

$V_s$  is multiplied by  $\phi_{col} = 0.00$

$s/d = 0.3125$

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

$f = 0.95$ , for fully-wrapped sections

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

In (11.3)  $\sin \theta + \cos \theta$  is replaced with  $(\cot \theta + \cot \alpha) \sin \alpha$  which is more a generalised expression, where  $\theta$  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  $\alpha_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

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

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$ , 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:  $V_s + V_f \leq 261735.249$

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

Calculation of Shear Strength at edge 2,  $V_{r2} = 385374.211$

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

$V_{Col0} = 385374.211$

$k_{nl} = 1$  (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)

$f'_c = 24.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 7.3565446E-012$

$\nu_u = 7.8886091E-031$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$

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

$f_y = 525.00$

$s = 100.00$

$V_s$  is multiplied by  $Col = 0.00$

$s/d = 0.3125$

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

$f = 0.95$ , for fully-wrapped sections

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

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

This later relation, considered as a function  $V_f(\theta)$ , 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,  $t_{f1} = NL * t / \text{NoDir} = 1.016$

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

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 261735.249$

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

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

At local axis: 2

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

At local axis: 3

Integration Section: (a)

Section Type: rccs

Constant Properties

Knowledge Factor,  $\phi = 1.00$

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

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

## Stepwise Properties

Bending Moment,  $M = -1.0733\text{E}+007$

Shear Force,  $V2 = -3575.956$

Shear Force,  $V3 = -2.9854277\text{E}-013$

Axial Force,  $F = -4769.80$

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  $u_{l,R} = \gamma + p = 0.03797001$

$u = \gamma + p = 0.03797001$

- Calculation of  $\gamma$  -

$\gamma = (M_y * L_s / 3) / E_{eff} = 0.03297001$  ((4.29), Biskinis Phd))

$M_y = 2.8606\text{E}+008$

$L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3001.332

From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} * E_c * I_g = 8.6803\text{E}+012$

factor = 0.30

$A_g = 125663.706$

$f_c' = 24.00$

$N = 4769.80$

$E_c * I_g = 2.8934\text{E}+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $\gamma$  and  $M_y$  according to (7) - (8) in Biskinis and Fardis

$M_y = \text{Min}(M_{y\_ten}, M_{y\_com}) = 2.8606\text{E}+008$

$\gamma$  ((10a) or (10b)) = 1.6206346E-005

$M_{y\_ten}$  (8a) = 2.8606E+008

$\gamma_{ten}$  (7a) = 73.23937

error of function (7a) = 0.00140751

$M_{y\_com}$  (8b) = 4.0293E+008

$\gamma_{com}$  (7b) = 68.98129

error of function (7b) = -0.00043134

with  $e_y = 0.002625$

$e_{co} = 0.002$

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

$d_1 = 44.00$

$R = 200.00$

$v = 0.00134935$

$N = 4769.80$

$A_c = 125663.706$

$= 0.45352339$

with  $f_c' = ((12.3), \text{ACI 440}) = 28.12975$

$f_c = 24.00$

$f_l = 1.3173$

$k = 1$

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

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

$E_f = 64828.00$

Calculation of ratio  $l_b/l_d$

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

- Calculation of  $\rho$  -

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

with:

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

shear control ratio  $V_y E / V_{Col} E = 0.48361756$

$d = 0.00$

$s = 0.00$

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

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

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

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

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

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

$N_{UD} = 4769.80$

$A_g = 125663.706$

$f_{cE} = 24.00$

$f_{ytE} = f_{yIE} = 525.00$

$\rho_l = \text{Area\_Tot\_Long\_Rein} / (A_g) = 0.0243$

$f_{cE} = 24.00$

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

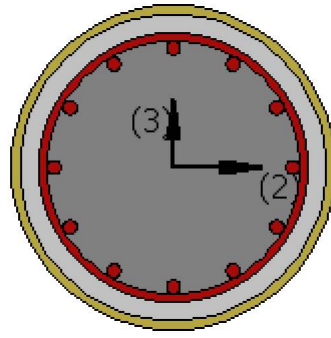
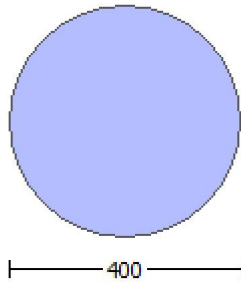
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: End

Local Axis: (2)



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

At local axis: 2

Integration Section: (b)

Section Type: rccs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 420.00$

Concrete Elasticity,  $E_c = 23025.204$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of  $\gamma$  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,  $f_c = f_{cm} = 24.00$

Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$

#####

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  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment,  $M_a = -1.0733E+007$

Shear Force,  $V_a = -3575.956$

EDGE -B-

Bending Moment,  $M_b = 0.09489048$

Shear Force,  $V_b = 3575.956$

BOTH EDGES

Axial Force,  $F = -4769.80$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

-Middle:  $As_{mid} = 1017.876$

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

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $VR = V_n = 314830.054$

$V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{Col0} = 314830.054$

$V_{Col} = 314830.054$

$k_n = 1.00$

displacement\_ductility\_demand = 0.05627203

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  $f'_c \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 0.09489048$

$V_u = 3575.956$

$d = 0.8 \cdot D = 320.00$

$N_u = 4769.80$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14:  $V_s = 165809.354$

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

$f_y = 420.00$

$s = 100.00$

$V_s$  is multiplied by  $\phi_{col} = 0.00$

$s/d = 0.3125$

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

$f = 0.95$ , for fully-wrapped sections

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

In (11.3)  $\sin \theta + \cos \theta$  is replaced with  $(\cot \theta + \cot \alpha) \sin \alpha$  which is more a generalised expression, where  $\theta$  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  $\alpha_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta = 45^\circ$  and  $\alpha = 90^\circ$

$V_f = \text{Min}(|V_f(45^\circ, 90^\circ)|, |V_f(-45^\circ, 90^\circ)|)$ , 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:  $V_s + V_f \leq 213705.936$

$b_w \cdot d = \frac{V_s + V_f}{f_e \cdot E_f \cdot t_{f1}} = 80424.772$

displacement\_ductility\_demand is calculated as  $\delta_u / y$

- Calculation of  $\delta_u / y$  for END B -

for rotation axis 3 and integ. section (b)

From analysis, chord rotation  $\phi = 0.00018545$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00329554$  ((4.29), Biskinis Phd))

$M_y = 2.8606 \text{E}+008$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 8.6803 \text{E}+012$

factor = 0.30  
Ag = 125663.706  
fc' = 24.00  
N = 4769.80  
Ec\*Ig = 2.8934E+013

Calculation of Yielding Moment My

Calculation of  $\rho_y$  and My according to (7) - (8) in Biskinis and Fardis

My = Min(My\_ten, My\_com) = 2.8606E+008  
 $\rho_y$  ((10a) or (10b)) = 1.6206346E-005  
My\_ten (8a) = 2.8606E+008  
 $\rho_{y\_ten}$  (7a) = 73.23937  
error of function (7a) = 0.00140751  
My\_com (8b) = 4.0293E+008  
 $\rho_{y\_com}$  (7b) = 68.98129  
error of function (7b) = -0.00043134  
with  $\rho_y$  = 0.002625  
 $\rho_{eco}$  = 0.002  
 $\rho_{apl}$  = 0.45 ((9c) in Biskinis and Fardis for FRP Wrap)  
d1 = 44.00  
R = 200.00  
 $\nu$  = 0.00134935  
N = 4769.80  
Ac = 125663.706  
 $\rho_{Ac}$  = 0.45352339  
with  $\rho_{fc}$  ((12.3), ACI 440) = 28.12975  
fc = 24.00  
fl = 1.3173  
k = 1  
Effective FRP thickness,  $t_f$  = NL\*t\*cos(b1) = 1.016  
 $\rho_{efe}$  ((12.5) and (12.7)) = 0.004  
Ef = 64828.00

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

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

At local axis: 2

Integration Section: (b)

## Calculation No. 6



column C1, Floor 1

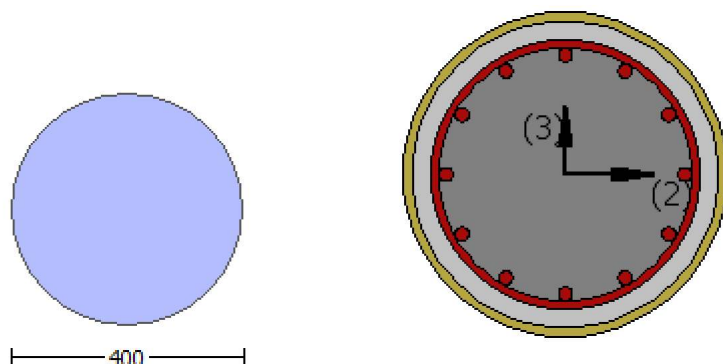
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

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,  $\gamma = 1.00$

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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,  $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Diameter,  $D = 400.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.72976

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

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = -2.2164346E-030$

EDGE -B-

Shear Force,  $V_b = 2.2164346E-030$

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,  $V_e/V_r = 0.48361756$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 186373.736$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.7956E+008$

$Mu_{1+} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.7956E+008$

$Mu_{2+} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

#### Calculation of $Mu_{1+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $M_u$

$M_u = 2.7956E+008$

$\phi = 1.06465$

$\phi' = 0.94240061$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$

conf. factor  $c = 1.72976$

$f_c = 24.00$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 656.25$

$l_b/l_d = 1.00$

$d_1 = 44.00$

$R = 200.00$

$v = 0.00133941$

$N = 4771.233$

$A_c = 125663.706$

$= \phi' \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.56255742$

#### Calculation of ratio $l_b/l_d$

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

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465  
' = 0.94240061  
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$   
conf. factor  $c = 1.72976$   
 $f_c = 24.00$   
From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $Ac = 125663.706$   
=  $\cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

Calculation of ratio  $l_b/d$

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

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465  
' = 0.94240061  
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$   
conf. factor  $c = 1.72976$   
 $f_c = 24.00$   
From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $Ac = 125663.706$   
=  $\cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

Calculation of ratio  $l_b/d$

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

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465

$\rho = 0.94240061$   
 error of function (3.68), Biskinis Phd = 47223.857  
 From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$   
 conf. factor  $c = 1.72976$   
 $f_c = 24.00$   
 From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $A_c = 125663.706$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 385374.211$

Calculation of Shear Strength at edge 1,  $V_{r1} = 385374.211$

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

$V_{Col0} = 385374.211$

$k_{nl} = 1$  (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)

$f_c' = 24.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.4753320E-011$

$\nu_u = 2.2164346E-030$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$

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

$f_y = 525.00$

$s = 100.00$

$V_s$  is multiplied by  $Col = 0.00$

$s/d = 0.3125$

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

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

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

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

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

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 261735.249$

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

Calculation of Shear Strength at edge 2,  $V_{r2} = 385374.211$

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

VColO = 385374.211  
knl = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)  
 $f_c' = 24.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.4753320E-011$   
 $\mu_u = 2.2164346E-030$   
 $d = 0.8 \cdot D = 320.00$   
 $N_u = 4771.233$   
 $A_g = 125663.706$   
From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$   
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$   
 $f_y = 525.00$   
 $s = 100.00$   
 $V_s$  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  $V_f(\alpha, a)$ , is implemented for every different fiber orientation  $\alpha$ ,  
as well as for 2 crack directions,  $\alpha = 45^\circ$  and  $\alpha = -45^\circ$  to take into consideration the cyclic seismic loading.  
orientation 1:  $\alpha = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|)$ , with:  
total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 370.00  
 $f_{fe} ((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
with  $f_u = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 261735.249$   
 $b_w \cdot d = \sqrt{2} \cdot d \cdot d / 4 = 80424.772$

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

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

Constant Properties

Knowledge Factor,  $\phi = 1.00$   
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$   
Concrete Elasticity,  $E_c = 23025.204$   
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,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
#####  
Diameter,  $D = 400.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.72976

Element Length,  $L = 3000.00$   
 Primary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_o/l_{ou}, \min \geq 1$ )  
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $\epsilon_{fu} = 0.01$   
 Number of directions,  $NoDir = 1$   
 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,  $V_a = 7.8886091E-031$   
 EDGE -B-  
 Shear Force,  $V_b = -7.8886091E-031$   
 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,  $V_e/V_r = 0.48361756$   
 Member Controlled by Flexure ( $V_e/V_r < 1$ )  
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 186373.736$   
 with  
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 2.7956E+008$   
 $\mu_{u1+} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination  
 $\mu_{u1-} = 2.7956E+008$ , 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  
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 2.7956E+008$   
 $\mu_{u2+} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination  
 $\mu_{u2-} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

#### Calculation of $\mu_{u1+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu_u$   
 $\mu_u = 2.7956E+008$

$= 1.06465$   
 $' = 0.94240061$   
 error of function (3.68), Biskinis Phd = 47223.857  
 From 5A.2, TBDY:  $f_{cc} = f_c^* \quad c = 41.51419$

conf. factor  $c = 1.72976$   
 $f_c = 24.00$   
 From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $A_c = 125663.706$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_1$ -

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.7956E+008$

$= 1.06465$   
 $' = 0.94240061$   
 error of function (3.68), Biskinis Phd = 47223.857  
 From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$   
 conf. factor  $c = 1.72976$   
 $f_c = 24.00$   
 From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $A_c = 125663.706$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_2$ +

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.7956E+008$

$= 1.06465$   
 $' = 0.94240061$   
 error of function (3.68), Biskinis Phd = 47223.857  
 From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$   
 conf. factor  $c = 1.72976$   
 $f_c = 24.00$   
 From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $A_c = 125663.706$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_2$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.7956 \times 10^8$

$$= 1.06465$$

$$' = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$

conf. factor  $c = 1.72976$

$f_c = 24.00$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00133941$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 385374.211$

Calculation of Shear Strength at edge 1,  $V_{r1} = 385374.211$

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

$$V_{colO} = 385374.211$$

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

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

$= 1$  (normal-weight concrete)

$f_c' = 24.00$ , but  $f_c^{0.5} \leq 8.3$  MPa ((22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$\mu_u = 7.3565446 \times 10^{-12}$$

$$V_u = 7.8886091 \times 10^{-31}$$

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

$$N_u = 4771.233$$

$$A_g = 125663.706$$

From ((11.5.4.8), ACI 318-14:  $V_s = 207261.692$

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

$$f_y = 525.00$$

$$s = 100.00$$

$V_s$  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  $\theta$  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  $\alpha_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

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

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

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

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

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 261735.249$

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

Calculation of Shear Strength at edge 2,  $V_{r2} = 385374.211$

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

$V_{\text{Col}0} = 385374.211$

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

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

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

$f'_c = 24.00$ , but  $f'_c \cdot 0.5 \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 7.3565446 \text{E-}012$

$\nu_u = 7.8886091 \text{E-}031$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$

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

$f_y = 525.00$

$s = 100.00$

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

$s/d = 0.3125$

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

$f = 0.95$ , for fully-wrapped sections

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

In (11.3)  $\sin \theta + \cos \theta$  is replaced with  $(\cot \theta + \cot \alpha) \sin \alpha$  which is more a generalised expression, where  $\theta$  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  $\alpha_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

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

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

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

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

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 261735.249$

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

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

At local axis: 2

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

At local axis: 2

Integration Section: (b)

Section Type: rccs

## Constant Properties

Knowledge Factor,  $\phi = 1.00$

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

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

## Stepwise Properties

Bending Moment,  $M = 8.1069813E-011$

Shear Force,  $V_2 = 3575.956$

Shear Force,  $V_3 = 2.9854277E-013$

Axial Force,  $F = -4769.80$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{slt} = 0.00$

-Compression:  $A_{slc} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Mean Diameter of Tension Reinforcement,  $D_bL = 18.00$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = u = 0.02147769$

$u = y + p = 0.02147769$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.01647769$  ((4.29), Biskinis Phd))

$M_y = 2.8606E+008$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 8.6803E+012$

factor = 0.30

$A_g = 125663.706$

$f_c' = 24.00$

$N = 4769.80$

$E_c * I_g = 2.8934E+013$

### Calculation of Yielding Moment $M_y$

Calculation of  $\gamma$  and  $M_y$  according to (7) - (8) in Biskinis and Fardis

$M_y = \min(M_{y\_ten}, M_{y\_com}) = 2.8606E+008$   
 $\gamma ((10a) \text{ or } (10b)) = 1.6206346E-005$   
 $M_{y\_ten} (8a) = 2.8606E+008$   
 $\gamma_{ten} (7a) = 73.23937$   
error of function (7a) = 0.00140751  
 $M_{y\_com} (8b) = 4.0293E+008$   
 $\gamma_{com} (7b) = 68.98129$   
error of function (7b) = -0.00043134  
with  $e_y = 0.002625$   
 $e_{co} = 0.002$   
 $a_{pl} = 0.45 ((9c) \text{ in Biskinis and Fardis for FRP Wrap})$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00134935$   
 $N = 4769.80$   
 $A_c = 125663.706$   
 $= 0.45352339$   
with  $f_c^* ((12.3), \text{ACI } 440) = 28.12975$   
 $f_c = 24.00$   
 $f_l = 1.3173$   
 $k = 1$   
Effective FRP thickness,  $t_f = N L^* t \cos(b_1) = 1.016$   
 $e_{fe} ((12.5) \text{ and } (12.7)) = 0.004$   
 $E_f = 64828.00$

### Calculation of ratio $l_b/l_d$

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

### - Calculation of $p$ -

From table 10-9:  $p = 0.005$

with:

- Columns controlled by inadequate development or splicing along the clear height because  $l_b/l_d < 1$   
shear control ratio  $V_y E / V_{co} I_{OE} = 0.48361756$   
 $d = 0.00$   
 $s = 0.00$   
 $t = 2 A_v / (d c^* s) + 4 t_f / D^* (f_{fe} / f_s) = 0.00$   
 $A_v = 78.53982$ , is the area of the circular stirrup  
 $d c = D - 2^* \text{cover} - \text{Hoop Diameter} = 340.00$   
The term  $2 t_f / b w^* (f_{fe} / f_s)$  is implemented to account for FRP contribution  
where  $f = 2 t_f / b w$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength  
All these variables have already been given in Shear control ratio calculation.  
 $N U D = 4769.80$   
 $A_g = 125663.706$   
 $f_{cE} = 24.00$   
 $f_{yE} = f_{yI} = 525.00$   
 $p_l = \text{Area\_Tot\_Long\_Rein} / (A_g) = 0.0243$   
 $f_{cE} = 24.00$

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

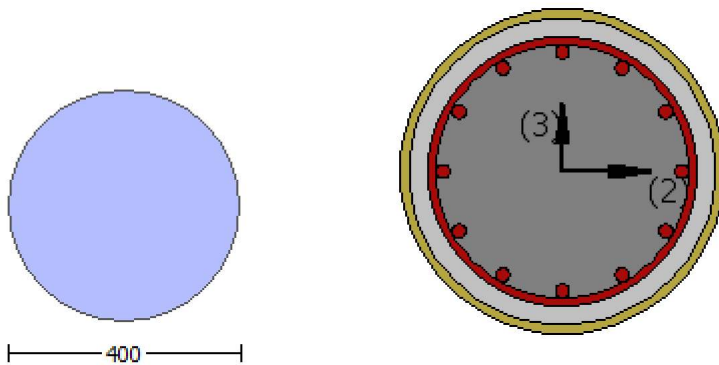
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: End

Local Axis: (3)



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

At local axis: 3

Integration Section: (b)

Section Type: rccs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 420.00$

Concrete Elasticity,  $E_c = 23025.204$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of  $\gamma$  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,  $f_c = f_{cm} = 24.00$

Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$

#####

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  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

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

#### Stepwise Properties

EDGE -A-  
 Bending Moment,  $M_a = 8.1497328E-010$   
 Shear Force,  $V_a = -2.9854277E-013$   
 EDGE -B-  
 Bending Moment,  $M_b = 8.1069813E-011$   
 Shear Force,  $V_b = 2.9854277E-013$   
 BOTH EDGES  
 Axial Force,  $F = -4769.80$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $As_{lt} = 0.00$   
   -Compression:  $As_{lc} = 3053.628$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $As_{l,ten} = 1017.876$   
   -Compression:  $As_{l,com} = 1017.876$   
   -Middle:  $As_{l,mid} = 1017.876$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = V_n = 314830.054$   
 $V_n ((10.3), ASCE 41-17) = knl * V_{Col0} = 314830.054$   
 $V_{Col} = 314830.054$   
 $knl = 1.00$   
 $displacement\_ductility\_demand = 0.00$

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).

$\beta = 1$  (normal-weight concrete)  
 $f'_c = 16.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 8.1069813E-011$   
 $V_u = 2.9854277E-013$   
 $d = 0.8 * D = 320.00$   
 $N_u = 4769.80$   
 $A_g = 125663.706$   
 From (11.5.4.8), ACI 318-14:  $V_s = 165809.354$   
 $A_v = \sqrt{2} * A_{stirrup} = 123370.055$   
 $f_y = 420.00$   
 $s = 100.00$   
 $V_s$  is multiplied by  $\phi_{col} = 0.00$   
 $s/d = 0.3125$   
 $V_f ((11-3)-(11.4), ACI 440) = 194961.134$   
 $\phi = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL * t / NoDir = 1.016$

$d_{fv} = d$  (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:  $V_s + V_f \leq 213705.936$   
 $b_w \cdot d = \frac{d^2}{4} = 80424.772$

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

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

From analysis, chord rotation  $\theta = 1.0954441E-020$   
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.01647769$  ((4.29), Biskinis Phd))  
 $M_y = 2.8606E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 1500.00  
 From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 8.6803E+012$   
 $\text{factor} = 0.30$   
 $A_g = 125663.706$   
 $f'_c = 24.00$   
 $N = 4769.80$   
 $E_c \cdot I_g = 2.8934E+013$

Calculation of Yielding Moment  $M_y$

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

$M_y = \min(M_{y\_ten}, M_{y\_com}) = 2.8606E+008$   
 $y$  ((10a) or (10b)) = 1.6206346E-005  
 $M_{y\_ten}$  (8a) = 2.8606E+008  
 $\frac{\Delta}{y}$  (7a) = 73.23937  
 error of function (7a) = 0.00140751  
 $M_{y\_com}$  (8b) = 4.0293E+008  
 $\frac{\Delta}{y}$  (7b) = 68.98129  
 error of function (7b) = -0.00043134  
 with  $e_y = 0.002625$   
 $e_{co} = 0.002$   
 $a_{pl} = 0.45$  ((9c) in Biskinis and Fardis for FRP Wrap)  
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00134935$   
 $N = 4769.80$   
 $A_c = 125663.706$   
 $= 0.45352339$   
 with  $f'_c$  ((12.3), ACI 440) = 28.12975  
 $f_c = 24.00$   
 $f_l = 1.3173$   
 $k = 1$   
 Effective FRP thickness,  $t_f = N \cdot L \cdot \cos(b_1) = 1.016$   
 $e_{fe}$  ((12.5) and (12.7)) = 0.004  
 $E_f = 64828.00$

Calculation of ratio  $l_b/d$

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

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

## Calculation No. 8

column C1, Floor 1

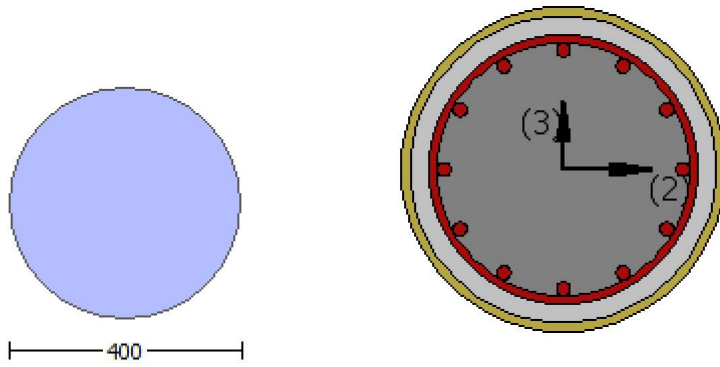
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\phi$ )

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,  $\gamma = 1.00$

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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,  $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Diameter,  $D = 400.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.72976

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

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

#### FRP Wrapping Data

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

#### Stepwise Properties

At local axis: 3  
EDGE -A-  
Shear Force,  $V_a = -2.2164346E-030$   
EDGE -B-  
Shear Force,  $V_b = 2.2164346E-030$   
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,  $V_e/V_r = 0.48361756$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 186373.736$   
with  
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 2.7956E+008$   
 $\mu_{u1+} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination  
 $\mu_{u1-} = 2.7956E+008$ , 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  
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 2.7956E+008$   
 $\mu_{u2+} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination  
 $\mu_{u2-} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

#### Calculation of $\mu_{u1+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu_u$   
 $\mu_u = 2.7956E+008$

$\lambda = 1.06465$   
 $\lambda' = 0.94240061$   
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$   
conf. factor  $c = 1.72976$   
 $f_c = 24.00$   
From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \min(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 656.25$   
 $l_b/l_d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$



$$N = 4771.233$$

$$Ac = 125663.706$$

$$= *Min(1, 1.25*(lb/d)^{2/3}) = 0.56255742$$

Calculation of ratio lb/d

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

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
 $Mu = 2.7956E+008$

$$= 1.06465$$

$$' = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TDY:  $f_{cc} = f_c * c = 41.51419$

conf. factor  $c = 1.72976$

$f_c = 24.00$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y * Min(1, 1.25*(lb/d)^{2/3}) = 656.25$

$lb/d = 1.00$

$d1 = 44.00$

$R = 200.00$

$v = 0.00133941$

$N = 4771.233$

$Ac = 125663.706$

$= *Min(1, 1.25*(lb/d)^{2/3}) = 0.56255742$

Calculation of ratio lb/d

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

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
 $Mu = 2.7956E+008$

$$= 1.06465$$

$$' = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TDY:  $f_{cc} = f_c * c = 41.51419$

conf. factor  $c = 1.72976$

$f_c = 24.00$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y * Min(1, 1.25*(lb/d)^{2/3}) = 656.25$

$lb/d = 1.00$

$d1 = 44.00$

$R = 200.00$

$v = 0.00133941$

$N = 4771.233$

$Ac = 125663.706$

$= *Min(1, 1.25*(lb/d)^{2/3}) = 0.56255742$

Calculation of ratio lb/d

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

## Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465  
' = 0.94240061  
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY:  $f_{cc} = f_c' \cdot c = 41.51419$   
conf. factor  $c = 1.72976$   
 $f_c = 24.00$   
From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $A_c = 125663.706$   
=  $\cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

## Calculation of ratio lb/d

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 385374.211$

Calculation of Shear Strength at edge 1,  $V_{r1} = 385374.211$   
 $V_{r1} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{Col0}$   
 $V_{Col0} = 385374.211$   
 $k_{nl} = 1$  (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)  
 $f_c' = 24.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $M_u = 1.4753320E-011$   
 $V_u = 2.2164346E-030$   
 $d = 0.8 \cdot D = 320.00$   
 $N_u = 4771.233$   
 $A_g = 125663.706$   
From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$   
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$   
 $f_y = 525.00$   
 $s = 100.00$   
 $V_s$  is multiplied by  $Col = 0.00$   
 $s/d = 0.3125$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 194961.134  
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
where  $a$  is the angle of the crack direction (see KANEPE).  
This later relation, considered as a function  $V_f(\theta, a)$ , 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:  $\theta = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:  
total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 370.00

$f_{fe} ((11-5), \text{ACI } 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 261735.249$   
 $b_w \cdot d = \frac{A_s \cdot d}{4} = 80424.772$

Calculation of Shear Strength at edge 2,  $V_{r2} = 385374.211$   
 $V_{r2} = V_{Col} ((10.3), \text{ASCE } 41-17) = k_{nl} \cdot V_{Col0}$   
 $V_{Col0} = 385374.211$   
 $k_{nl} = 1$  (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)  
 $f'_c = 24.00$ , but  $f_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.4753320E-011$   
 $\nu_u = 2.2164346E-030$   
 $d = 0.8 \cdot D = 320.00$   
 $N_u = 4771.233$   
 $A_g = 125663.706$   
 From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$   
 $A_v = \frac{A_{stirrup}}{2} = 123370.055$   
 $f_y = 525.00$   
 $s = 100.00$   
 $V_s$  is multiplied by  $\phi_{Col} = 0.00$   
 $s/d = 0.3125$   
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 194961.134$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 370.00  
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 261735.249$   
 $b_w \cdot d = \frac{A_s \cdot d}{4} = 80424.772$

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

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

Constant Properties

Knowledge Factor,  $\phi = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$   
 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,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
 #####  
 Diameter,  $D = 400.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.72976  
 Element Length,  $L = 3000.00$   
 Primary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_o/l_{ou,min} \geq 1$ )  
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $\epsilon_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i: 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2  
 EDGE -A-  
 Shear Force,  $V_a = 7.8886091E-031$   
 EDGE -B-  
 Shear Force,  $V_b = -7.8886091E-031$   
 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,  $V_e/V_r = 0.48361756$   
 Member Controlled by Flexure ( $V_e/V_r < 1$ )  
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 186373.736$   
 with  
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 2.7956E+008$   
 $\mu_{u1+} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction  
 which is defined for the static loading combination  
 $\mu_{u1-} = 2.7956E+008$ , 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  
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 2.7956E+008$   
 $\mu_{u2+} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction  
 which is defined for the the static loading combination  
 $\mu_{u2-} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment  
 direction which is defined for the the static loading combination

Calculation of  $\mu_{u1+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465  
' = 0.94240061  
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY: fcc = fc\* c = 41.51419  
conf. factor c = 1.72976  
fc = 24.00  
From 10.3.5, ASCE41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 656.25  
lb/d = 1.00  
d1 = 44.00  
R = 200.00  
v = 0.00133941  
N = 4771.233  
Ac = 125663.706  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.56255742

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465  
' = 0.94240061  
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY: fcc = fc\* c = 41.51419  
conf. factor c = 1.72976  
fc = 24.00  
From 10.3.5, ASCE41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 656.25  
lb/d = 1.00  
d1 = 44.00  
R = 200.00  
v = 0.00133941  
N = 4771.233  
Ac = 125663.706  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.56255742

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465  
' = 0.94240061  
error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$   
 conf. factor  $c = 1.72976$   
 $f_c = 24.00$   
 From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $A_c = 125663.706$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_2$ -

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.7956E+008$

$= 1.06465$   
 $' = 0.94240061$   
 error of function (3.68), Biskinis Phd = 47223.857  
 From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$   
 conf. factor  $c = 1.72976$   
 $f_c = 24.00$   
 From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $A_c = 125663.706$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 385374.211$

Calculation of Shear Strength at edge 1,  $V_{r1} = 385374.211$   
 $V_{r1} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = k_{nl} \cdot V_{CoI0}$   
 $V_{CoI0} = 385374.211$   
 $k_{nl} = 1$  (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)  
 $f_c' = 24.00$ , but  $f_c'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu = 7.3565446E-012$   
 $V_u = 7.8886091E-031$   
 $d = 0.8 \cdot D = 320.00$   
 $N_u = 4771.233$   
 $A_g = 125663.706$

From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$

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

$f_y = 525.00$

$s = 100.00$

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

$s/d = 0.3125$

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

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

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

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

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 261735.249$

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

Calculation of Shear Strength at edge 2,  $V_{r2} = 385374.211$

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

$V_{\text{ColO}} = 385374.211$

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

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

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

$f'_c = 24.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 7.3565446E-012$

$\nu_u = 7.8886091E-031$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$

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

$f_y = 525.00$

$s = 100.00$

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

$s/d = 0.3125$

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

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

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

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

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 261735.249$

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

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

At local axis: 2

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

At local axis: 3

Integration Section: (b)

Section Type: rccs

#### Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = 0.09489048$

Shear Force,  $V_2 = 3575.956$

Shear Force,  $V_3 = 2.9854277E-013$

Axial Force,  $F = -4769.80$

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  $u_{i,R} = \gamma \cdot u = 0.00829554$

$u = \gamma \cdot u_p = 0.00829554$

- Calculation of  $\gamma$  -

$\gamma = (M_y \cdot L_s / 3) / E_{eff} = 0.00329554 ((4.29), \text{Biskinis Phd})$



$M_y = 2.8606E+008$   
 $L_s = M/V$  (with  $L_s > 0.1*L$  and  $L_s < 2*L$ ) = 300.00  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 8.6803E+012$   
 $factor = 0.30$   
 $A_g = 125663.706$   
 $f_c' = 24.00$   
 $N = 4769.80$   
 $E_c * I_g = 2.8934E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $\phi_y$  and  $M_y$  according to (7) - (8) in Biskinis and Fardis

$M_y = \min(M_{y\_ten}, M_{y\_com}) = 2.8606E+008$   
 $\phi_y$  ((10a) or (10b)) =  $1.6206346E-005$   
 $M_{y\_ten}$  (8a) =  $2.8606E+008$   
 $\phi_{y\_ten}$  (7a) = 73.23937  
 $error$  of function (7a) = 0.00140751  
 $M_{y\_com}$  (8b) =  $4.0293E+008$   
 $\phi_{y\_com}$  (7b) = 68.98129  
 $error$  of function (7b) = -0.00043134  
 with  $e_y = 0.002625$   
 $e_{co} = 0.002$   
 $a_{pl} = 0.45$  ((9c) in Biskinis and Fardis for FRP Wrap)  
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00134935$   
 $N = 4769.80$   
 $A_c = 125663.706$   
 $= 0.45352339$   
 with  $f_c' ((12.3), ACl 440) = 28.12975$   
 $f_c = 24.00$   
 $f_l = 1.3173$   
 $k = 1$   
 Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $e_{fe} ((12.5) \text{ and } (12.7)) = 0.004$   
 $E_f = 64828.00$

Calculation of ratio  $I_b/I_d$

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

- Calculation of  $\phi_p$  -

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

with:

- Columns controlled by inadequate development or splicing along the clear height because  $I_b/I_d < 1$   
 $shear \text{ control ratio } V_{yE}/V_{ColOE} = 0.48361756$   
 $d = 0.00$   
 $s = 0.00$   
 $t = 2 * A_v / (d_c * s) + 4 * t_f / D * (f_{fe} / f_s) = 0.00$   
 $A_v = 78.53982$ , is the area of the circular stirrup  
 $d_c = D - 2 * cover - \text{Hoop Diameter} = 340.00$   
 The term  $2 * t_f / bw * (f_{fe} / f_s)$  is implemented to account for FRP contribution  
 where  $f = 2 * t_f / bw$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength  
 All these variables have already been given in Shear control ratio calculation.  
 $NUD = 4769.80$   
 $A_g = 125663.706$   
 $f_cE = 24.00$   
 $f_{ytE} = f_{yIE} = 525.00$   
 $\phi_l = Area\_Tot\_Long\_Rein / (A_g) = 0.0243$   
 $f_cE = 24.00$

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

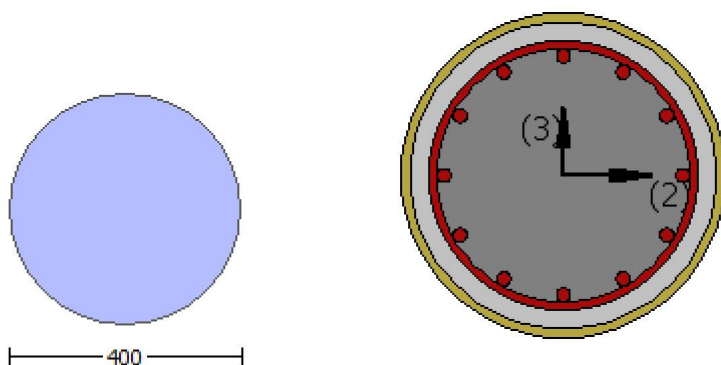
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (2)



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

At local axis: 2

Integration Section: (a)

Section Type: rccs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 420.00$

Concrete Elasticity,  $E_c = 23025.204$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of  $\gamma$  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,  $f_c = f_{cm} = 24.00$

Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$

#####

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  
 Adequate Lap Length ( $l_o/l_{ou,min} = l_b/l_d \geq 1$ )  
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness, t = 1.016  
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $\epsilon_{fu} = 0.01$   
 Number of directions, NoDir = 1  
 Fiber orientations,  $b_i = 0.00^\circ$   
 Number of layers, NL = 1  
 Radius of rounding corners, R = 40.00

#### Stepwise Properties

EDGE -A-  
 Bending Moment,  $M_a = -8.5847E+006$   
 Shear Force,  $V_a = -2860.289$   
 EDGE -B-  
 Bending Moment,  $M_b = 0.07589976$   
 Shear Force,  $V_b = 2860.289$   
 BOTH EDGES  
 Axial Force,  $F = -4770.087$   
 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  $V_R = V_n = 264268.023$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{CoI0} = 264268.023$   
 $V_{CoI} = 264268.023$   
 $k_n = 1.00$   
 displacement\_ductility\_demand = 0.00810469

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)  
 $M/Vd = 4.00$   
 $M_u = 8.5847E+006$   
 $V_u = 2860.289$   
 $d = 0.8 \cdot D = 320.00$   
 $N_u = 4770.087$   
 $A_g = 125663.706$   
 From (11.5.4.8), ACI 318-14:  $V_s = 165809.354$   
 $A_v = A_{st\_stirrup} / 2 = 123370.055$   
 $f_y = 420.00$   
 $s = 100.00$   
 $V_s$  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  $Vf(\theta, a)$ , 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:  $\theta = b1 + 90^\circ = 90.00$

$Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, a1)|)$ , 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:  $Vs + Vf \leq 213705.936$

$bw \cdot d = \frac{Vd}{4} = 80424.772$

displacement\_ductility\_demand is calculated as  $\delta / y$

- Calculation of  $\delta / y$  for END A -

for rotation axis 3 and integ. section (a)

From analysis, chord rotation  $\theta = 0.00026721$

$y = (My \cdot Ls / 3) / Eleff = 0.03297001$  ((4.29), Biskinis Phd))

$My = 2.8606E+008$

$Ls = M/V$  (with  $Ls > 0.1 \cdot L$  and  $Ls < 2 \cdot L$ ) = 3001.332

From table 10.5, ASCE 41\_17:  $Eleff = \text{factor} \cdot Ec \cdot Ig = 8.6803E+012$

factor = 0.30

$Ag = 125663.706$

$fc' = 24.00$

$N = 4770.087$

$Ec \cdot Ig = 2.8934E+013$

Calculation of Yielding Moment  $My$

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

$My = \text{Min}(My_{ten}, My_{com}) = 2.8606E+008$

$y$  ((10a) or (10b)) = 1.6206348E-005

$My_{ten}$  (8a) = 2.8606E+008

$\theta_{ten}$  (7a) = 73.23937

error of function (7a) = 0.00140752

$My_{com}$  (8b) = 4.0293E+008

$\theta_{com}$  (7b) = 68.98129

error of function (7b) = -0.00043134

with  $ey = 0.002625$

$eco = 0.002$

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

$d1 = 44.00$

$R = 200.00$

$v = 0.00134943$

$N = 4770.087$

$Ac = 125663.706$

$= 0.45352339$

with  $fc^*$  ((12.3), ACI 440) = 28.12975

$fc = 24.00$

$fl = 1.3173$

$k = 1$

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

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

$Ef = 64828.00$

Calculation of ratio  $Ib/d$

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

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

At local axis: 2

Integration Section: (a)

## Calculation No. 10

column C1, Floor 1

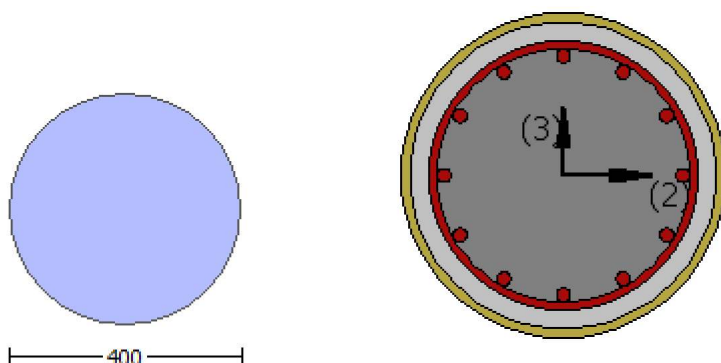
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

Edge: Start

Local Axis: (2)



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

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rccs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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,  $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Diameter,  $D = 400.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.72976  
 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  
 Adequate Lap Length ( $l_o/l_{ou}, \min > 1$ )  
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness, t = 1.016  
 Tensile Strength,  $f_{fu}$  = 1055.00  
 Tensile Modulus,  $E_f$  = 64828.00  
 Elongation,  $\epsilon_{fu}$  = 0.01  
 Number of directions, NoDir = 1  
 Fiber orientations,  $b_i$ : 0.00°  
 Number of layers, NL = 1  
 Radius of rounding corners, R = 40.00

#### Stepwise Properties

At local axis: 3  
 EDGE -A-  
 Shear Force,  $V_a$  = -2.2164346E-030  
 EDGE -B-  
 Shear Force,  $V_b$  = 2.2164346E-030  
 BOTH EDGES  
 Axial Force, F = -4771.233  
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{st}$  = 0.00  
   -Compression:  $A_{sc}$  = 3053.628  
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{st,ten}$  = 1017.876  
   -Compression:  $A_{st,com}$  = 1017.876  
   -Middle:  $A_{st,mid}$  = 1017.876

Calculation of Shear Capacity ratio,  $V_e/V_r$  = 0.48361756  
 Member Controlled by Flexure ( $V_e/V_r < 1$ )  
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 186373.736$   
 with  
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 2.7956\text{E}+008$   
 $\mu_{u1+} = 2.7956\text{E}+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination  
 $\mu_{u1-} = 2.7956\text{E}+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 2.7956\text{E}+008$   
 $\mu_{u2+} = 2.7956\text{E}+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination  
 $\mu_{u2-} = 2.7956\text{E}+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

#### Calculation of $\mu_{u1+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu_u$   
 $\mu_u = 2.7956\text{E}+008$

= 1.06465  
 ' = 0.94240061  
 error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$   
conf. factor  $c = 1.72976$   
 $f_c = 24.00$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $Ac = 125663.706$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_1$ -

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.7956E+008$

$= 1.06465$   
 $' = 0.94240061$   
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$   
conf. factor  $c = 1.72976$   
 $f_c = 24.00$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $Ac = 125663.706$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_2$ +

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.7956E+008$

$= 1.06465$   
 $' = 0.94240061$   
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$   
conf. factor  $c = 1.72976$   
 $f_c = 24.00$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$

$$A_c = 125663.706$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_2$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.7956 \times 10^8$

$$= 1.06465$$

$$\rho = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$

conf. factor  $c = 1.72976$

$f_c = 24.00$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 200.00$

$v = 0.00133941$

$N = 4771.233$

$A_c = 125663.706$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 385374.211$

Calculation of Shear Strength at edge 1,  $V_{r1} = 385374.211$

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

$V_{CoI0} = 385374.211$

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

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

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

$f_c' = 24.00$ , but  $f_c'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.4753320 \times 10^{-11}$

$V_u = 2.2164346 \times 10^{-30}$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$

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

$f_y = 525.00$

$s = 100.00$

$V_s$  is multiplied by  $CoI = 0.00$

$s/d = 0.3125$

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

$f = 0.95$ , for fully-wrapped sections

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



In (11.3)  $\sin \theta + \cos \theta$  is replaced with  $(\cot \theta + \cot \alpha) \sin \alpha$  which is more a generalised expression, where  $\theta$  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  $\alpha_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \alpha_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L * t / N_{\text{Dir}} = 1.016$   
 $d_{fv} = d$  (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:  $V_s + V_f \leq 261735.249$   
 $b_w * d = \rho_s * d^2 / 4 = 80424.772$

Calculation of Shear Strength at edge 2,  $V_{r2} = 385374.211$   
 $V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_n l * V_{Col0}$   
 $V_{Col0} = 385374.211$   
 $k_n l = 1$  (zero step-static loading)

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

$\rho_s = 1$  (normal-weight concrete)  
 $f_c' = 24.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M / V d = 2.00$   
 $\mu_u = 1.4753320E-011$   
 $\nu_u = 2.2164346E-030$   
 $d = 0.8 * D = 320.00$   
 $N_u = 4771.233$   
 $A_g = 125663.706$   
 From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$   
 $A_v = \rho_s / 2 * A_{\text{stirrup}} = 123370.055$   
 $f_y = 525.00$   
 $s = 100.00$   
 $V_s$  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  
 $w_f / s_f = 1$  (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  $\theta$  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  $\alpha_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \alpha_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L * t / N_{\text{Dir}} = 1.016$   
 $d_{fv} = d$  (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:  $V_s + V_f \leq 261735.249$   
 $b_w * d = \rho_s * d^2 / 4 = 80424.772$

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,  $\phi = 1.00$

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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,  $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Diameter,  $D = 400.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.72976

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

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

## Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = 7.8886091E-031$

EDGE -B-

Shear Force,  $V_b = -7.8886091E-031$

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,  $V_e/V_r = 0.48361756$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 186373.736$

with

$M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 2.7956E+008$

$\mu_{u1+} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{u1-} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.7956E+008$$

$M_{u2+} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

-----  
Calculation of  $M_{u1+}$   
-----

-----  
Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $M_u$   
 $M_u = 2.7956E+008$   
-----

$$\begin{aligned} &= 1.06465 \\ &' = 0.94240061 \\ &\text{error of function (3.68), Biskinis Phd} = 47223.857 \\ &\text{From 5A.2, TBDY: } f_{cc} = f_c' \cdot c = 41.51419 \\ &\text{conf. factor } c = 1.72976 \\ &f_c = 24.00 \\ &\text{From 10.3.5, ASCE41-17, Final value of } f_y: f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25 \\ &l_b/d = 1.00 \\ &d_1 = 44.00 \\ &R = 200.00 \\ &v = 0.00133941 \\ &N = 4771.233 \\ &A_c = 125663.706 \\ &= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742 \end{aligned}$$

-----  
Calculation of ratio  $l_b/d$   
-----

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

Calculation of  $M_{u1-}$   
-----

-----  
Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $M_u$   
 $M_u = 2.7956E+008$   
-----

$$\begin{aligned} &= 1.06465 \\ &' = 0.94240061 \\ &\text{error of function (3.68), Biskinis Phd} = 47223.857 \\ &\text{From 5A.2, TBDY: } f_{cc} = f_c' \cdot c = 41.51419 \\ &\text{conf. factor } c = 1.72976 \\ &f_c = 24.00 \\ &\text{From 10.3.5, ASCE41-17, Final value of } f_y: f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25 \\ &l_b/d = 1.00 \\ &d_1 = 44.00 \\ &R = 200.00 \\ &v = 0.00133941 \\ &N = 4771.233 \\ &A_c = 125663.706 \\ &= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742 \end{aligned}$$

-----  
Calculation of ratio  $l_b/d$   
-----

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

Calculation of  $M_{u2+}$   
-----

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465  
' = 0.94240061  
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY: fcc = fc\* c = 41.51419  
conf. factor c = 1.72976  
fc = 24.00  
From 10.3.5, ASCE41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 656.25  
lb/d = 1.00  
d1 = 44.00  
R = 200.00  
v = 0.00133941  
N = 4771.233  
Ac = 125663.706  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.56255742

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465  
' = 0.94240061  
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY: fcc = fc\* c = 41.51419  
conf. factor c = 1.72976  
fc = 24.00  
From 10.3.5, ASCE41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 656.25  
lb/d = 1.00  
d1 = 44.00  
R = 200.00  
v = 0.00133941  
N = 4771.233  
Ac = 125663.706  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.56255742

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 385374.211

Calculation of Shear Strength at edge 1, Vr1 = 385374.211  
Vr1 = VCol ((10.3), ASCE 41-17) = knl\*VColO  
VColO = 385374.211  
knl = 1 (zero step-static loading)

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

$\lambda = 1$  (normal-weight concrete)  
 $f'_c = 24.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 7.3565446E-012$   
 $\mu_v = 7.8886091E-031$   
 $d = 0.8 \cdot D = 320.00$   
 $N_u = 4771.233$   
 $A_g = 125663.706$   
 From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$   
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$   
 $f_y = 525.00$   
 $s = 100.00$   
 $V_s$  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:  $\theta = 45^\circ$   
 $V_f = \min(|V_f(45, \theta)|, |V_f(-45, a)|)$ , 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:  $V_s + V_f \leq 261735.249$   
 $b_w \cdot d = \sqrt{4} \cdot d = 80424.772$

Calculation of Shear Strength at edge 2,  $V_{r2} = 385374.211$   
 $V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{Col0}$   
 $V_{Col0} = 385374.211$   
 $k_n = 1$  (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)  
 $f'_c = 24.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 7.3565446E-012$   
 $\mu_v = 7.8886091E-031$   
 $d = 0.8 \cdot D = 320.00$   
 $N_u = 4771.233$   
 $A_g = 125663.706$   
 From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$   
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$   
 $f_y = 525.00$   
 $s = 100.00$   
 $V_s$  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:  $\theta = 45^\circ$   
 $V_f = \min(|V_f(45, \theta)|, |V_f(-45, a)|)$ , 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:  $V_s + V_f \leq 261735.249$

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

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

At local axis: 2

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

At local axis: 2

Integration Section: (a)

Section Type: rccs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

Bending Moment,  $M = 6.5482280E-010$

Shear Force,  $V_2 = -2860.289$

Shear Force,  $V_3 = -2.3879448E-013$

Axial Force,  $F = -4770.087$

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,  $D_{bL} = 18.00$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = \frac{u}{R} = \frac{0.06958736}{1} = 0.06958736$   
 $u = y + p = 0.06958736$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.01647769$  ((4.29), Biskinis Phd))  
 $M_y = 2.8606E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 1500.00  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 8.6803E+012$   
factor = 0.30  
 $A_g = 125663.706$   
 $f_c' = 24.00$   
 $N = 4770.087$   
 $E_c * I_g = 2.8934E+013$

Calculation of Yielding Moment  $M_y$

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

$M_y = \min(M_{y\_ten}, M_{y\_com}) = 2.8606E+008$   
 $y$  ((10a) or (10b)) =  $1.6206348E-005$   
 $M_{y\_ten}$  (8a) =  $2.8606E+008$   
 $y_{ten}$  (7a) = 73.23937  
error of function (7a) = 0.00140752  
 $M_{y\_com}$  (8b) =  $4.0293E+008$   
 $y_{com}$  (7b) = 68.98129  
error of function (7b) = -0.00043134  
with  $e_y = 0.002625$   
 $e_{co} = 0.002$   
 $apl = 0.45$  ((9c) in Biskinis and Fardis for FRP Wrap)  
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00134943$   
 $N = 4770.087$   
 $A_c = 125663.706$   
 $= 0.45352339$   
with  $f_c' = 24.00$  ((12.3), ACI 440) = 28.12975  
 $f_l = 1.3173$   
 $k = 1$   
Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $e_{fe}$  ((12.5) and (12.7)) = 0.004  
 $E_f = 64828.00$

Calculation of ratio  $l_b/d$

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

- Calculation of  $p$  -

From table 10-9:  $p = 0.05310967$

with:

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

shear control ratio  $V_y E / V_{col} O E = 0.48361756$

$d = 0.00$

$s = 0.00$

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

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

$d_c = D - 2 * cover$  - Hoop Diameter = 340.00

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

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

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

NUD = 4770.087

Ag = 125663.706

f<sub>cE</sub> = 24.00

f<sub>ytE</sub> = f<sub>ylE</sub> = 525.00

pl = Area\_Tot\_Long\_Rein/(Ag) = 0.0243

f<sub>cE</sub> = 24.00

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

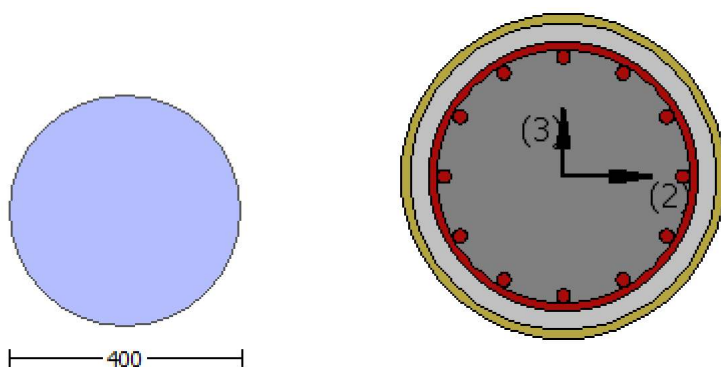
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



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

At local axis: 3

Integration Section: (a)

Section Type: rccs

Constant Properties

Knowledge Factor, = 1.00

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

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

Consequently:

Existing material of Primary Member: Concrete Strength, f<sub>c</sub> = f<sub>c\_lower\_bound</sub> = 16.00

Existing material of Primary Member: Steel Strength, f<sub>s</sub> = f<sub>s\_lower\_bound</sub> = 420.00

Concrete Elasticity, E<sub>c</sub> = 23025.204

Steel Elasticity, E<sub>s</sub> = 200000.00



#####

Note: Especially for the calculation of  $\gamma$  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,  $f_c = f_{cm} = 24.00$

Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$

#####

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  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

EDGE -A-

Bending Moment,  $M_a = 6.5482280E-010$

Shear Force,  $V_a = -2.3879448E-013$

EDGE -B-

Bending Moment,  $M_b = 6.1892434E-011$

Shear Force,  $V_b = 2.3879448E-013$

BOTH EDGES

Axial Force,  $F = -4770.087$

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  $V_R = \phi V_n = 314830.111$

$V_n$  ((10.3), ASCE 41-17) =  $k_n l V_{CoIO} = 314830.111$

$V_{CoI} = 314830.111$

$k_n l = 1.00$

displacement\_ductility\_demand = 0.00

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

= 1 (normal-weight concrete)

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

$M/V_d = 2.00$

$M_u = 6.5482280E-010$

$V_u = 2.3879448E-013$

$d = 0.8 \cdot D = 320.00$

$N_u = 4770.087$

$A_g = 125663.706$   
 From (11.5.4.8), ACI 318-14:  $V_s = 165809.354$   
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$   
 $f_y = 420.00$   
 $s = 100.00$   
 $V_s$  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:  $\theta = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$ , 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:  $V_s + V_f \leq 213705.936$   
 $b_w \cdot d = \sqrt{2} \cdot d^2 / 4 = 80424.772$

displacement\_ductility\_demand is calculated as  $\delta / y$

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

From analysis, chord rotation  $\theta = 2.3261784\text{E-}020$   
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.01647769$  ((4.29), Biskinis Phd))  
 $M_y = 2.8606\text{E+}008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 1500.00  
 From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 8.6803\text{E+}012$   
 factor = 0.30  
 $A_g = 125663.706$   
 $f_c' = 24.00$   
 $N = 4770.087$   
 $E_c \cdot I_g = 2.8934\text{E+}013$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta$  and  $M_y$  according to (7) - (8) in Biskinis and Fardis

$M_y = \text{Min}(M_{y\_ten}, M_{y\_com}) = 2.8606\text{E+}008$   
 $y$  ((10a) or (10b)) = 1.6206348E-005  
 $M_{y\_ten}$  (8a) = 2.8606E+008  
 $\delta_{ten}$  (7a) = 73.23937  
 error of function (7a) = 0.00140752  
 $M_{y\_com}$  (8b) = 4.0293E+008  
 $\delta_{com}$  (7b) = 68.98129  
 error of function (7b) = -0.00043134  
 with  $e_y = 0.002625$   
 $e_{co} = 0.002$   
 $a_{pl} = 0.45$  ((9c) in Biskinis and Fardis for FRP Wrap)  
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00134943$   
 $N = 4770.087$   
 $A_c = 125663.706$   
 $= 0.45352339$   
 with  $f_c^*$  ((12.3), ACI 440) = 28.12975

$f_c = 24.00$   
 $f_l = 1.3173$   
 $k = 1$   
Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $e_{fe} ((12.5) \text{ and } (12.7)) = 0.004$   
 $E_f = 64828.00$

Calculation of ratio  $I_b/I_d$

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

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

At local axis: 3

Integration Section: (a)

## Calculation No. 12

column C1, Floor 1

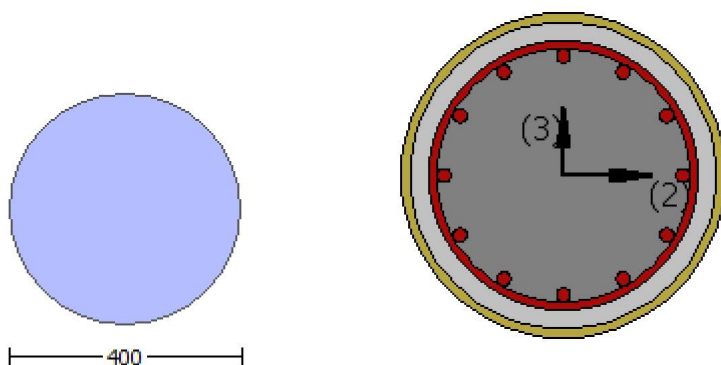
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

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,  $\gamma = 1.00$

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$   
 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,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
 #####  
 Diameter,  $D = 400.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.72976  
 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  
 Adequate Lap Length ( $l_o/l_{ou,min} >= 1$ )  
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $e_{fu} = 0.01$   
 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,  $V_a = -2.2164346E-030$   
 EDGE -B-  
 Shear Force,  $V_b = 2.2164346E-030$   
 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,  $V_e/V_r = 0.48361756$   
 Member Controlled by Flexure ( $V_e/V_r < 1$ )  
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 186373.736$   
 with  
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 2.7956E+008$   
 $\mu_{u1+} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction  
 which is defined for the static loading combination  
 $\mu_{u1-} = 2.7956E+008$ , 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  
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 2.7956E+008$   
 $\mu_{u2+} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction  
 which is defined for the the static loading combination  
 $\mu_{u2-} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment  
 direction which is defined for the the static loading combination

Calculation of  $\mu_{u1+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465  
' = 0.94240061  
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY: fcc = fc\* c = 41.51419  
conf. factor c = 1.72976  
fc = 24.00  
From 10.3.5, ASCE41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 656.25  
lb/d = 1.00  
d1 = 44.00  
R = 200.00  
v = 0.00133941  
N = 4771.233  
Ac = 125663.706  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.56255742

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465  
' = 0.94240061  
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY: fcc = fc\* c = 41.51419  
conf. factor c = 1.72976  
fc = 24.00  
From 10.3.5, ASCE41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 656.25  
lb/d = 1.00  
d1 = 44.00  
R = 200.00  
v = 0.00133941  
N = 4771.233  
Ac = 125663.706  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.56255742

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465  
' = 0.94240061  
error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$   
conf. factor  $c = 1.72976$   
 $f_c = 24.00$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $A_c = 125663.706$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_2$ -

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.7956E+008$

$= 1.06465$   
 $' = 0.94240061$   
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$   
conf. factor  $c = 1.72976$   
 $f_c = 24.00$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $A_c = 125663.706$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 385374.211$

Calculation of Shear Strength at edge 1,  $V_{r1} = 385374.211$   
 $V_{r1} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = k_{nl} \cdot V_{CoI0}$   
 $V_{CoI0} = 385374.211$   
 $k_{nl} = 1$  (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)  
 $f_c' = 24.00$ , but  $f_c'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu = 1.4753320E-011$   
 $V_u = 2.2164346E-030$   
 $d = 0.8 \cdot D = 320.00$   
 $N_u = 4771.233$   
 $A_g = 125663.706$

From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$

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

$f_y = 525.00$

$s = 100.00$

$V_s$  is multiplied by  $Col = 0.00$

$s/d = 0.3125$

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

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

total thickness per orientation,  $tf_1 = NL \cdot t / \text{NoDir} = 1.016$

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

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 261735.249$

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

Calculation of Shear Strength at edge 2,  $V_{r2} = 385374.211$

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

$V_{Col0} = 385374.211$

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

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

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

$f'_c = 24.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.4753320E-011$

$\nu_u = 2.2164346E-030$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$

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

$f_y = 525.00$

$s = 100.00$

$V_s$  is multiplied by  $Col = 0.00$

$s/d = 0.3125$

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

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

total thickness per orientation,  $tf_1 = NL \cdot t / \text{NoDir} = 1.016$

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

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 261735.249$

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

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,  $\gamma = 1.00$

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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,  $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Diameter,  $D = 400.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.72976

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

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = 7.8886091E-031$

EDGE -B-

Shear Force,  $V_b = -7.8886091E-031$

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 ,  $V_e/V_r = 0.48361756$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 186373.736$

with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 2.7956\text{E}+008$

$\mu_{1+} = 2.7956\text{E}+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{1-} = 2.7956\text{E}+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 2.7956\text{E}+008$

$\mu_{2+} = 2.7956\text{E}+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 2.7956\text{E}+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

-----  
Calculation of  $\mu_{1+}$   
-----

-----  
Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu_u$

$\mu_u = 2.7956\text{E}+008$   
-----

$\phi = 1.06465$

$\phi' = 0.94240061$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TB DY:  $f_{cc} = f_c \cdot c = 41.51419$

conf. factor  $c = 1.72976$

$f_c = 24.00$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 200.00$

$v = 0.00133941$

$N = 4771.233$

$A_c = 125663.706$

$= \phi \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$   
-----

Calculation of ratio  $l_b/d$   
-----

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

Calculation of  $\mu_{1-}$   
-----

-----  
Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu_u$

$\mu_u = 2.7956\text{E}+008$   
-----

$\phi = 1.06465$

$\phi' = 0.94240061$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TB DY:  $f_{cc} = f_c \cdot c = 41.51419$

conf. factor  $c = 1.72976$

$f_c = 24.00$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 200.00$

$v = 0.00133941$

$N = 4771.233$

$A_c = 125663.706$

$= \phi \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$   
-----

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_{2+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.7956E+008$

$$= 1.06465$$

$$' = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$

conf. factor  $c = 1.72976$

$f_c = 24.00$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00133941$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_{2-}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.7956E+008$

$$= 1.06465$$

$$' = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$

conf. factor  $c = 1.72976$

$f_c = 24.00$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00133941$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 385374.211$

Calculation of Shear Strength at edge 1,  $V_{r1} = 385374.211$

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

$V_{ColO} = 385374.211$

$k_{nl} = 1$  (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)

$f'_c = 24.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 7.3565446E-012$

$V_u = 7.8886091E-031$

$d = 0.8 * D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$

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

$f_y = 525.00$

$s = 100.00$

$V_s$  is multiplied by  $Col = 0.00$

$s/d = 0.3125$

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

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:

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

$d_{fv} = d$  (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:  $V_s + V_f \leq 261735.249$

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

Calculation of Shear Strength at edge 2,  $V_{r2} = 385374.211$

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

$V_{ColO} = 385374.211$

$k_{nl} = 1$  (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)

$f'_c = 24.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 7.3565446E-012$

$V_u = 7.8886091E-031$

$d = 0.8 * D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$

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

$f_y = 525.00$

$s = 100.00$

$V_s$  is multiplied by  $Col = 0.00$

$s/d = 0.3125$

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

$f = 0.95$ , for fully-wrapped sections

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

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , 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,  $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (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:  $V_s + V_f \leq 261735.249$   
 $b_w \cdot d = \sqrt[4]{d^3 \cdot V_s / 4} = 80424.772$

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

Start Of Calculation of Chord Rotation Capacity for element: column CC1 of floor 1  
 At local axis: 3  
 Integration Section: (a)  
 Section Type: rccs

#### Constant Properties

Knowledge Factor,  $\gamma = 1.00$   
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.  
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
 Consequently:  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$   
 Concrete Elasticity,  $E_c = 23025.204$   
 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  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_b / l_d \geq 1$ )  
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $e_{fu} = 0.01$   
 Number of directions,  $\text{NoDir} = 1$   
 Fiber orientations,  $b_i: 0.00^\circ$   
 Number of layers,  $NL = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -8.5847E+006$   
 Shear Force,  $V_2 = -2860.289$   
 Shear Force,  $V_3 = -2.3879448E-013$   
 Axial Force,  $F = -4770.087$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $A_{st} = 1272.345$

-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  $u_R = \gamma + p = 0.08607968$   
 $u = \gamma + p = 0.08607968$

- Calculation of  $\gamma$  -

$\gamma = (M_y * L_s / 3) / E_{eff} = 0.03297001$  ((4.29), Biskinis Phd))  
 $M_y = 2.8606E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3001.332  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 8.6803E+012$   
 $factor = 0.30$   
 $A_g = 125663.706$   
 $f_c' = 24.00$   
 $N = 4770.087$   
 $E_c * I_g = 2.8934E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $\gamma$  and  $M_y$  according to (7) - (8) in Biskinis and Fardis

$M_y = \min(M_{y\_ten}, M_{y\_com}) = 2.8606E+008$   
 $\gamma$  ((10a) or (10b)) = 1.6206348E-005  
 $M_{y\_ten}$  (8a) = 2.8606E+008  
 $\gamma_{ten}$  (7a) = 73.23937  
 error of function (7a) = 0.00140752  
 $M_{y\_com}$  (8b) = 4.0293E+008  
 $\gamma_{com}$  (7b) = 68.98129  
 error of function (7b) = -0.00043134  
 with  $e_y = 0.002625$   
 $e_{co} = 0.002$   
 $a_{pl} = 0.45$  ((9c) in Biskinis and Fardis for FRP Wrap)  
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00134943$   
 $N = 4770.087$   
 $A_c = 125663.706$   
 $= 0.45352339$   
 with  $f_c^*$  ((12.3), ACI 440) = 28.12975  
 $f_c = 24.00$   
 $f_l = 1.3173$   
 $k = 1$   
 Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $e_{fe}$  ((12.5) and (12.7)) = 0.004  
 $E_f = 64828.00$

Calculation of ratio  $l_b / l_d$

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

- Calculation of  $p$  -

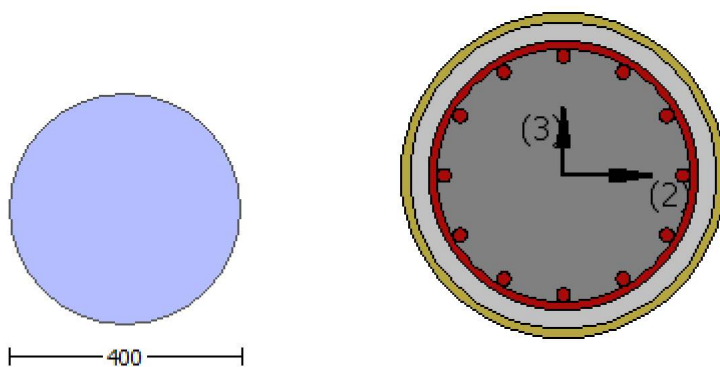
From table 10-9:  $p = 0.05310967$   
 with:

- Columns controlled by inadequate development or splicing along the clear height because  $l_b/l_d < 1$   
 shear control ratio  $V_{yE}/V_{ColOE} = 0.48361756$   
 $d = 0.00$   
 $s = 0.00$   
 $t = 2 \cdot A_v / (d_c \cdot s) + 4 \cdot t_f / D \cdot (f_{fe} / f_s) = 0.00$   
 $A_v = 78.53982$ , 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.  
 $NUD = 4770.087$   
 $Ag = 125663.706$   
 $f_{cE} = 24.00$   
 $f_{yE} = f_{yI} = 525.00$   
 $\rho_l = \text{Area\_Tot\_Long\_Rein} / (Ag) = 0.0243$   
 $f_{cE} = 24.00$

-----  
 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: Life Safety (data interpolation between analysis steps 1 and 2)  
 Analysis: Uniform +X  
 Check: Shear capacity  $V_{Rd}$   
 Edge: End  
 Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column CC1 of floor 1  
 At local axis: 2  
 Integration Section: (b)  
 Section Type: rccs  
 Constant Properties

Knowledge Factor,  $\gamma = 1.00$   
 Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.  
 Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17  
 Consequently:  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 420.00$   
 Concrete Elasticity,  $E_c = 23025.204$   
 Steel Elasticity,  $E_s = 200000.00$   
 #####  
 Note: Especially for the calculation of  $\gamma$  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,  $f_c = f_{cm} = 24.00$   
 Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$   
 #####  
 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  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_o/l_{ou,min} = l_b/d \geq 1$ )  
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $\epsilon_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i: 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

EDGE -A-  
 Bending Moment,  $M_a = -8.5847E+006$   
 Shear Force,  $V_a = -2860.289$   
 EDGE -B-  
 Bending Moment,  $M_b = 0.07589976$   
 Shear Force,  $V_b = 2860.289$   
 BOTH EDGES  
 Axial Force,  $F = -4770.087$   
 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,  $D_{bL,ten} = 18.00$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = \phi V_n = 314830.111$   
 $V_n ((10.3), ASCE 41-17) = k_n l * V_{CoI0} = 314830.111$   
 $V_{CoI} = 314830.111$   
 $k_n l = 1.00$   
 $displacement\_ductility\_demand = 0.04501013$

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + \phi * V_F$ '

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

= 1 (normal-weight concrete)

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

$M/Vd = 2.00$

$\mu_u = 0.07589976$

$V_u = 2860.289$

$d = 0.8 \cdot D = 320.00$

$N_u = 4770.087$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14:  $V_s = 165809.354$

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

$f_y = 420.00$

$s = 100.00$

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

$s/d = 0.3125$

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

$f = 0.95$ , for fully-wrapped sections

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

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

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

orientation 1:  $\theta = 45^\circ$   $\theta = 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$ , 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:  $V_s + V_f \leq 213705.936$

$b_w \cdot d = \frac{V_u}{f_y} = 80424.772$

displacement ductility demand is calculated as  $\delta_u / y$

- Calculation of  $\delta_u / y$  for END B -

for rotation axis 3 and integ. section (b)

From analysis, chord rotation  $\theta = 0.00014833$

$y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00329554$  ((4.29), Biskinis Phd))

$M_y = 2.8606 \text{E}+008$

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

From table 10.5, ASCE 41\_17:  $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 8.6803 \text{E}+012$

factor = 0.30

$A_g = 125663.706$

$f'_c = 24.00$

$N = 4770.087$

$E_c \cdot I_g = 2.8934 \text{E}+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta_u$  and  $M_y$  according to (7) - (8) in Biskinis and Fardis

$M_y = \text{Min}(M_{y_{\text{ten}}}, M_{y_{\text{com}}}) = 2.8606 \text{E}+008$

$y$  ((10a) or (10b)) = 1.6206348E-005

$M_{y_{\text{ten}}} (8a) = 2.8606 \text{E}+008$

$\delta_{y_{\text{ten}}} (7a) = 73.23937$

error of function (7a) = 0.00140752

$M_{y_{\text{com}}} (8b) = 4.0293 \text{E}+008$

$\delta_{y_{\text{com}}} (7b) = 68.98129$

error of function (7b) = -0.00043134

with  $e_y = 0.002625$



$\epsilon_{co} = 0.002$   
 $\alpha_{pl} = 0.45$  ((9c) in Biskinis and Fardis for FRP Wrap)  
 $d_1 = 44.00$   
 $R = 200.00$   
 $\nu = 0.00134943$   
 $N = 4770.087$   
 $A_c = 125663.706$   
 $= 0.45352339$   
 with  $f_c^*$  ((12.3), ACI 440) = 28.12975  
 $f_c = 24.00$   
 $f_l = 1.3173$   
 $k = 1$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $\epsilon_{fe}$  ((12.5) and (12.7)) = 0.004  
 $E_f = 64828.00$

Calculation of ratio  $l_b/d$

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

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

At local axis: 2

Integration Section: (b)

## Calculation No. 14

column C1, Floor 1

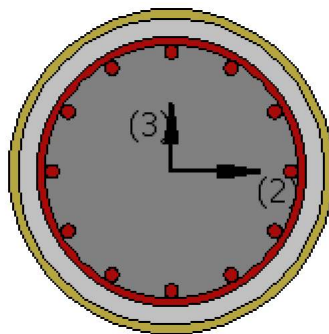
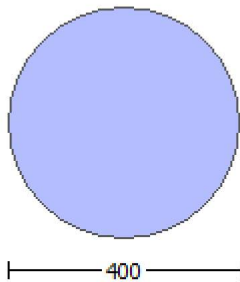
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

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,  $\gamma = 1.00$

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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,  $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Diameter,  $D = 400.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.72976

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

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

### Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = -2.2164346E-030$

EDGE -B-

Shear Force,  $V_b = 2.2164346E-030$

BOTH EDGES

Axial Force,  $F = -4771.233$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $A_{sc} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.48361756$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 186373.736$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.7956E+008$

$M_{u1+} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment

direction which is defined for the static loading combination

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.7956E+008$$

$M_{u2+} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 2.7956E+008$ , 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),  $M_u$   
 $M_u = 2.7956E+008$

$$= 1.06465$$

$$\lambda = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TB DY:  $f_{cc} = f_c \cdot \lambda = 41.51419$

conf. factor  $\lambda = 1.72976$

$$f_c = 24.00$$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00133941$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \lambda \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of  $M_{u1-}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $M_u$   
 $M_u = 2.7956E+008$

$$= 1.06465$$

$$\lambda = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TB DY:  $f_{cc} = f_c \cdot \lambda = 41.51419$

conf. factor  $\lambda = 1.72976$

$$f_c = 24.00$$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00133941$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \lambda \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of  $M_{u2+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465  
' = 0.94240061  
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY: fcc = fc\* c = 41.51419  
conf. factor c = 1.72976  
fc = 24.00  
From 10.3.5, ASCE41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 656.25  
lb/d = 1.00  
d1 = 44.00  
R = 200.00  
v = 0.00133941  
N = 4771.233  
Ac = 125663.706  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.56255742

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465  
' = 0.94240061  
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY: fcc = fc\* c = 41.51419  
conf. factor c = 1.72976  
fc = 24.00  
From 10.3.5, ASCE41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 656.25  
lb/d = 1.00  
d1 = 44.00  
R = 200.00  
v = 0.00133941  
N = 4771.233  
Ac = 125663.706  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.56255742

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 385374.211

Calculation of Shear Strength at edge 1, Vr1 = 385374.211

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

VColO = 385374.211

knl = 1 (zero step-static loading)

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

$\lambda = 1$  (normal-weight concrete)  
 $f'_c = 24.00$ , but  $f'_c \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.4753320E-011$   
 $\mu_v = 2.2164346E-030$   
 $d = 0.8 \cdot D = 320.00$   
 $N_u = 4771.233$   
 $A_g = 125663.706$   
 From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$   
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$   
 $f_y = 525.00$   
 $s = 100.00$   
 $V_s$  is multiplied by  $\lambda = 1.00$   
 $s/d = 0.3125$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 194961.134  
 $\lambda = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin \theta + \cos \theta$  is replaced with  $(\cot \theta + \cot \alpha) \sin \alpha$  which is more a generalised expression,  
 where  $\theta$  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  $\alpha_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = 45^\circ$   
 $V_f = \min(|V_f(45, \theta)|, |V_f(-45, \theta)|)$ , 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  
 $E_f = 64828.00$   
 $f_{fe} = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 261735.249$   
 $b_w \cdot d = 80424.772$

Calculation of Shear Strength at edge 2,  $V_{r2} = 385374.211$   
 $V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $\lambda \cdot V_{Col}$   
 $V_{Col} = 385374.211$   
 $\lambda = 1$  (zero step-static loading)

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

$\lambda = 1$  (normal-weight concrete)  
 $f'_c = 24.00$ , but  $f'_c \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.4753320E-011$   
 $\mu_v = 2.2164346E-030$   
 $d = 0.8 \cdot D = 320.00$   
 $N_u = 4771.233$   
 $A_g = 125663.706$   
 From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$   
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$   
 $f_y = 525.00$   
 $s = 100.00$   
 $V_s$  is multiplied by  $\lambda = 1.00$   
 $s/d = 0.3125$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 194961.134  
 $\lambda = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin \theta + \cos \theta$  is replaced with  $(\cot \theta + \cot \alpha) \sin \alpha$  which is more a generalised expression,  
 where  $\theta$  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  $\alpha_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = 45^\circ$   
 $V_f = \min(|V_f(45, \theta)|, |V_f(-45, \theta)|)$ , 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

```

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 <= 261735.249
bw*d = *d*d/4 = 80424.772
-----

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

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

Constant Properties
-----
Knowledge Factor, = 1.00
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, fc = fcm = 24.00
Existing material of Primary Member: Steel Strength, fs = fsm = 525.00
Concrete Elasticity, Ec = 23025.204
Steel Elasticity, Es = 200000.00
#####
Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, fs = 1.25*fsm = 656.25
#####
Diameter, D = 400.00
Cover Thickness, c = 25.00
Mean Confinement Factor overall section = 1.72976
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
Adequate Lap Length (lo/lou,min>=1)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, ffu = 1055.00
Tensile Modulus, Ef = 64828.00
Elongation, efu = 0.01
Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00
-----

Stepwise Properties
-----
At local axis: 2
EDGE -A-
Shear Force, Va = 7.8886091E-031
EDGE -B-
Shear Force, Vb = -7.8886091E-031
BOTH EDGES
Axial Force, F = -4771.233
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00

```

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

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.48361756$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 186373.736$   
 with

$M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 2.7956E+008$

$\mu_{u1+} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{u1-} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 2.7956E+008$

$\mu_{u2+} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{u2-} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $\mu_{u1+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu_u$   
 $\mu_u = 2.7956E+008$

$$= 1.06465$$

$$\lambda = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TB DY:  $f_{cc} = f_c^* \quad c = 41.51419$

conf. factor  $c = 1.72976$

$$f_c = 24.00$$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00133941$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \lambda \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_{u1-}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu_u$   
 $\mu_u = 2.7956E+008$

$$= 1.06465$$

$$\lambda = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TB DY:  $f_{cc} = f_c^* \quad c = 41.51419$

conf. factor  $c = 1.72976$

$$f_c = 24.00$$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00133941$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_{2+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$

$$\mu = 2.7956 \times 10^8$$

$$= 1.06465$$

$$' = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$

$$\text{conf. factor } c = 1.72976$$

$$f_c = 24.00$$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00133941$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_{2-}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$

$$\mu = 2.7956 \times 10^8$$

$$= 1.06465$$

$$' = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$

$$\text{conf. factor } c = 1.72976$$

$$f_c = 24.00$$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00133941$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$



Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 385374.211$

Calculation of Shear Strength at edge 1,  $V_{r1} = 385374.211$

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

$V_{Col0} = 385374.211$

$k_n l = 1$  (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)

$f'_c = 24.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 7.3565446E-012$

$V_u = 7.8886091E-031$

$d = 0.8D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$

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

$f_y = 525.00$

$s = 100.00$

$V_s$  is multiplied by  $Col = 0.00$

$s/d = 0.3125$

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

$f = 0.95$ , for fully-wrapped sections

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

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

This later relation, considered as a function  $V_f(\theta, a)$ , 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,  $t_{f1} = N_L t / N_{Dir} = 1.016$

$d_{fv} = d$  (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:  $V_s + V_f \leq 261735.249$

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

Calculation of Shear Strength at edge 2,  $V_{r2} = 385374.211$

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

$V_{Col0} = 385374.211$

$k_n l = 1$  (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)

$f'_c = 24.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 7.3565446E-012$

$V_u = 7.8886091E-031$

$d = 0.8D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$

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

$f_y = 525.00$

$s = 100.00$

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

$s/d = 0.3125$

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

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , 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), 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:  $V_s + V_f \leq 261735.249$

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

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

At local axis: 2

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

At local axis: 2

Integration Section: (b)

Section Type: rccs

Constant Properties

-----  
Knowledge Factor,  $\phi = 1.00$

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

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

## Stepwise Properties

Bending Moment,  $M = 6.1892434\text{E-}011$

Shear Force,  $V2 = 2860.289$

Shear Force,  $V3 = 2.3879448\text{E-}013$

Axial Force,  $F = -4770.087$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_{lt} = 0.00$

-Compression:  $As_{lc} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Mean Diameter of Tension Reinforcement,  $DbL = 18.00$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{l,R} = \gamma + p = 0.06958736$

$u = \gamma + p = 0.06958736$

- Calculation of  $\gamma$  -

$\gamma = (M_y * L_s / 3) / E_{eff} = 0.01647769$  ((4.29), Biskinis Phd))

$M_y = 2.8606\text{E+}008$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} * E_c * I_g = 8.6803\text{E+}012$

factor = 0.30

$A_g = 125663.706$

$f_c' = 24.00$

$N = 4770.087$

$E_c * I_g = 2.8934\text{E+}013$

Calculation of Yielding Moment  $M_y$

Calculation of  $\gamma$  and  $M_y$  according to (7) - (8) in Biskinis and Fardis

$M_y = \text{Min}(M_{y\_ten}, M_{y\_com}) = 2.8606\text{E+}008$

$\gamma$  ((10a) or (10b)) = 1.6206348E-005

$M_{y\_ten}$  (8a) = 2.8606E+008

$\gamma_{ten}$  (7a) = 73.23937

error of function (7a) = 0.00140752

$M_{y\_com}$  (8b) = 4.0293E+008

$\gamma_{com}$  (7b) = 68.98129

error of function (7b) = -0.00043134

with  $e_y = 0.002625$

$e_{co} = 0.002$

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

$d_1 = 44.00$

$R = 200.00$

$v = 0.00134943$

$N = 4770.087$

$A_c = 125663.706$

$= 0.45352339$

with  $f_c' = ((12.3), \text{ACI 440}) = 28.12975$

$f_c = 24.00$

$f_l = 1.3173$

$k = 1$

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

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

$E_f = 64828.00$

Calculation of ratio  $l_b/l_d$

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

- Calculation of  $\rho$  -

From table 10-9:  $\rho = 0.05310967$

with:

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

shear control ratio  $V_y E / V_{ColOE} = 0.48361756$

$d = 0.00$

$s = 0.00$

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

$A_v = 78.53982$ , 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.

$N_{UD} = 4770.087$

$A_g = 125663.706$

$f_{cE} = 24.00$

$f_{ytE} = f_{yIE} = 525.00$

$\rho_l = \text{Area\_Tot\_Long\_Rein} / (A_g) = 0.0243$

$f_{cE} = 24.00$

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

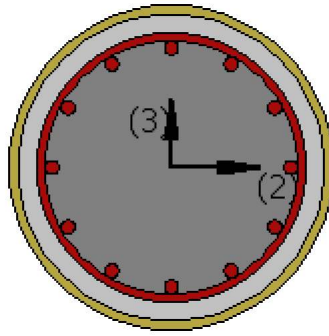
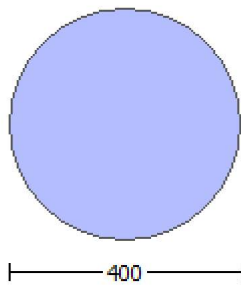
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: End

Local Axis: (3)



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

At local axis: 3

Integration Section: (b)

Section Type: rccs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 420.00$

Concrete Elasticity,  $E_c = 23025.204$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of  $\gamma$  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,  $f_c = f_{cm} = 24.00$

Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$

#####

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  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment,  $M_a = 6.5482280E-010$

Shear Force,  $V_a = -2.3879448E-013$

EDGE -B-

Bending Moment,  $M_b = 6.1892434E-011$

Shear Force,  $V_b = 2.3879448E-013$

BOTH EDGES

Axial Force,  $F = -4770.087$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

-Middle:  $As_{mid} = 1017.876$

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

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $VR = V_n = 314830.111$

$V_n$  ((10.3), ASCE 41-17) =  $kn_l * V_{Col0} = 314830.111$

$V_{Col} = 314830.111$

$kn_l = 1.00$

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  $f'_c \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 6.1892434E-011$

$V_u = 2.3879448E-013$

$d = 0.8 * D = 320.00$

$N_u = 4770.087$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14:  $V_s = 165809.354$

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

$f_y = 420.00$

$s = 100.00$

$V_s$  is multiplied by  $Col = 0.00$

$s/d = 0.3125$

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

$f = 0.95$ , for fully-wrapped sections

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

In (11.3)  $\sin \alpha + \cos \alpha$  is replaced with  $(\cot \alpha + \cot \alpha) \sin \alpha$  which is more a generalised expression, where  $\alpha$  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  $\alpha_i$ , 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,  $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$  (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:  $V_s + V_f \leq 213705.936$

$b_w * d = A_v * d / 4 = 80424.772$

displacement\_ductility\_demand is calculated as  $\Delta / y$

- Calculation of  $\Delta / y$  for END B -

for rotation axis 2 and integ. section (b)

From analysis, chord rotation  $\theta = 8.7620949E-021$

$y = (M_y * L_s / 3) / E_{eff} = 0.01647769$  ((4.29), Biskinis Phd))

$M_y = 2.8606E+008$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} * E_c * I_g = 8.6803E+012$

factor = 0.30  
Ag = 125663.706  
fc' = 24.00  
N = 4770.087  
Ec\*Ig = 2.8934E+013

Calculation of Yielding Moment My

Calculation of  $\rho_y$  and My according to (7) - (8) in Biskinis and Fardis

My = Min(My\_ten, My\_com) = 2.8606E+008  
 $\rho_y$  ((10a) or (10b)) = 1.6206348E-005  
My\_ten (8a) = 2.8606E+008  
 $\rho_{y\_ten}$  (7a) = 73.23937  
error of function (7a) = 0.00140752  
My\_com (8b) = 4.0293E+008  
 $\rho_{y\_com}$  (7b) = 68.98129  
error of function (7b) = -0.00043134  
with  $\rho_y$  = 0.002625  
 $\rho_{eco}$  = 0.002  
 $\rho_{apl}$  = 0.45 ((9c) in Biskinis and Fardis for FRP Wrap)  
d1 = 44.00  
R = 200.00  
 $\nu$  = 0.00134943  
N = 4770.087  
Ac = 125663.706  
 $\rho_{Ac}$  = 0.45352339  
with  $\rho_{fc}$  ((12.3), ACI 440) = 28.12975  
fc = 24.00  
f1 = 1.3173  
k = 1  
Effective FRP thickness,  $t_f$  = NL\*t\*cos(b1) = 1.016  
 $\rho_{efe}$  ((12.5) and (12.7)) = 0.004  
Ef = 64828.00

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

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

At local axis: 3

Integration Section: (b)

**Calculation No. 16**

column C1, Floor 1

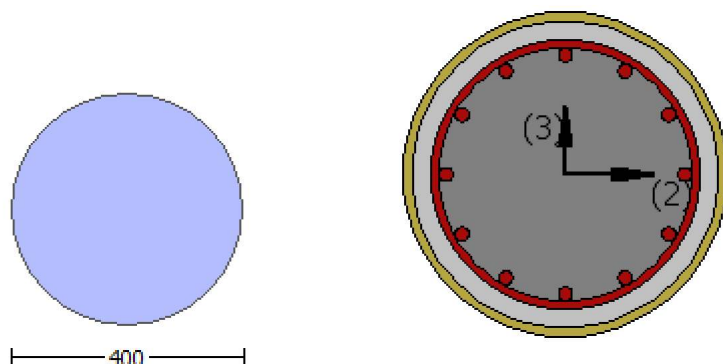
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

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,  $K = 1.00$

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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,  $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Diameter,  $D = 400.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.72976

Element Length,  $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$



Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = -2.2164346E-030$

EDGE -B-

Shear Force,  $V_b = 2.2164346E-030$

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,  $V_e/V_r = 0.48361756$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 186373.736$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.7956E+008$

$Mu_{1+} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.7956E+008$

$Mu_{2+} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

#### Calculation of $Mu_{1+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $M_u$

$M_u = 2.7956E+008$

$\phi = 1.06465$

$\phi' = 0.94240061$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$

conf. factor  $c = 1.72976$

$f_c = 24.00$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 200.00$

$v = 0.00133941$

$N = 4771.233$

$A_c = 125663.706$

$= \phi' \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

#### Calculation of ratio $l_b/d$

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

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465  
' = 0.94240061  
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$   
conf. factor  $c = 1.72976$   
 $f_c = 24.00$   
From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $A_c = 125663.706$   
=  $\cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

Calculation of ratio  $l_b/d$

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

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465  
' = 0.94240061  
error of function (3.68), Biskinis Phd = 47223.857  
From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$   
conf. factor  $c = 1.72976$   
 $f_c = 24.00$   
From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $A_c = 125663.706$   
=  $\cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

Calculation of ratio  $l_b/d$

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

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.7956E+008

= 1.06465

$\lambda = 0.94240061$   
 error of function (3.68), Biskinis Phd = 47223.857  
 From 5A.2, TBDY:  $f_{cc} = f_c \cdot \lambda = 41.51419$   
 conf. factor  $\lambda = 1.72976$   
 $f_c = 24.00$   
 From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $A_c = 125663.706$   
 $= \lambda \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 385374.211$

Calculation of Shear Strength at edge 1,  $V_{r1} = 385374.211$

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

$V_{Col0} = 385374.211$

$k_{nl} = 1$  (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)

$f_c' = 24.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa ((22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.4753320E-011$

$\nu_u = 2.2164346E-030$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From ((11.5.4.8), ACI 318-14:  $V_s = 207261.692$

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

$f_y = 525.00$

$s = 100.00$

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

$s/d = 0.3125$

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

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

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

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

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

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From ((11-11), ACI 440:  $V_s + V_f \leq 261735.249$

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

Calculation of Shear Strength at edge 2,  $V_{r2} = 385374.211$

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

VCoIO = 385374.211  
knl = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)  
 $f_c' = 24.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.4753320E-011$   
 $\nu_u = 2.2164346E-030$   
 $d = 0.8 \cdot D = 320.00$   
 $N_u = 4771.233$   
 $A_g = 125663.706$   
From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$   
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$   
 $f_y = 525.00$   
 $s = 100.00$   
 $V_s$  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)  $\sin \theta + \cos \theta$  is replaced with  $(\cot \theta + \cot \alpha) \sin \alpha$  which is more a generalised expression,  
where  $\theta$  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  $\alpha_i$ ,  
as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \alpha_1)|)$ , with:  
total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 370.00  
 $f_{fe} ((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_{fe} = 0.004$ , from (11.6a), ACI 440  
with  $f_u = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 261735.249$   
 $b_w \cdot d = \sqrt{2} \cdot d \cdot d / 4 = 80424.772$

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

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

Constant Properties

Knowledge Factor,  $\phi = 1.00$   
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$   
Concrete Elasticity,  $E_c = 23025.204$   
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,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
#####  
Diameter,  $D = 400.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.72976

Element Length,  $L = 3000.00$   
 Primary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_o/l_{ou}, \min \geq 1$ )  
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $\epsilon_{fu} = 0.01$   
 Number of directions,  $NoDir = 1$   
 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,  $V_a = 7.8886091E-031$   
 EDGE -B-  
 Shear Force,  $V_b = -7.8886091E-031$   
 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,  $V_e/V_r = 0.48361756$   
 Member Controlled by Flexure ( $V_e/V_r < 1$ )  
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 186373.736$   
 with  
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 2.7956E+008$   
 $\mu_{u1+} = 2.7956E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination  
 $\mu_{u1-} = 2.7956E+008$ , 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  
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 2.7956E+008$   
 $\mu_{u2+} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination  
 $\mu_{u2-} = 2.7956E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

#### Calculation of $\mu_{u1+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu_u$   
 $\mu_u = 2.7956E+008$

$= 1.06465$   
 $' = 0.94240061$   
 error of function (3.68), Biskinis Phd = 47223.857  
 From 5A.2, TBDY:  $f_{cc} = f_c^* \quad c = 41.51419$

conf. factor  $c = 1.72976$   
 $f_c = 24.00$   
 From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $A_c = 125663.706$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_1$ -

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.7956E+008$

$= 1.06465$   
 $' = 0.94240061$   
 error of function (3.68), Biskinis Phd = 47223.857  
 From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$   
 conf. factor  $c = 1.72976$   
 $f_c = 24.00$   
 From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $A_c = 125663.706$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_2$ +

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.7956E+008$

$= 1.06465$   
 $' = 0.94240061$   
 error of function (3.68), Biskinis Phd = 47223.857  
 From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$   
 conf. factor  $c = 1.72976$   
 $f_c = 24.00$   
 From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00133941$   
 $N = 4771.233$   
 $A_c = 125663.706$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_2$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.7956 \times 10^8$

$$= 1.06465$$

$$' = 0.94240061$$

error of function (3.68), Biskinis Phd = 47223.857

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 41.51419$

conf. factor  $c = 1.72976$

$f_c = 24.00$

From 10.3.5, ASCE41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 656.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 200.00$$

$$v = 0.00133941$$

$$N = 4771.233$$

$$A_c = 125663.706$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.56255742$$

Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 385374.211$

Calculation of Shear Strength at edge 1,  $V_{r1} = 385374.211$

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

$$V_{colO} = 385374.211$$

$k_{nl} = 1$  (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)

$f_c' = 24.00$ , but  $f_c^{0.5} \leq 8.3$  MPa ((22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$\mu_u = 7.3565446 \times 10^{-12}$$

$$V_u = 7.8886091 \times 10^{-31}$$

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

$$N_u = 4771.233$$

$$A_g = 125663.706$$

From ((11.5.4.8), ACI 318-14:  $V_s = 207261.692$

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

$$f_y = 525.00$$

$$s = 100.00$$

$V_s$  is multiplied by  $\phi_{col} = 0.00$

$$s/d = 0.3125$$

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

$f = 0.95$ , for fully-wrapped sections

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

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

where  $\theta$  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  $\alpha_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

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

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

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

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

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 261735.249$

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

Calculation of Shear Strength at edge 2,  $V_{r2} = 385374.211$

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

$V_{\text{Col}0} = 385374.211$

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

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

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

$f'_c = 24.00$ , but  $f'_c \cdot 0.5 \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 7.3565446 \text{E-}012$

$\nu_u = 7.8886091 \text{E-}031$

$d = 0.8 \cdot D = 320.00$

$N_u = 4771.233$

$A_g = 125663.706$

From (11.5.4.8), ACI 318-14:  $V_s = 207261.692$

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

$f_y = 525.00$

$s = 100.00$

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

$s/d = 0.3125$

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

$f = 0.95$ , for fully-wrapped sections

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

In (11.3)  $\sin \theta + \cos \theta$  is replaced with  $(\cot \theta + \cot \alpha) \sin \alpha$  which is more a generalised expression, where  $\theta$  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  $\alpha_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

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

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

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

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

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 261735.249$

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

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

At local axis: 2

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

At local axis: 3

Integration Section: (b)

Section Type: rccs



## Constant Properties

Knowledge Factor,  $\phi = 1.00$

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

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

Consequently:

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

## Stepwise Properties

Bending Moment,  $M = 0.07589976$

Shear Force,  $V_2 = 2860.289$

Shear Force,  $V_3 = 2.3879448E-013$

Axial Force,  $F = -4770.087$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{slt} = 0.00$

-Compression:  $A_{slc} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Mean Diameter of Tension Reinforcement,  $D_bL = 18.00$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = u = 0.05640521$

$u = y + p = 0.05640521$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00329554$  ((4.29), Biskinis Phd))

$M_y = 2.8606E+008$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 8.6803E+012$

factor = 0.30

$A_g = 125663.706$

$f_c' = 24.00$

$N = 4770.087$

$E_c * I_g = 2.8934E+013$

#### Calculation of Yielding Moment $M_y$

Calculation of  $\gamma$  and  $M_y$  according to (7) - (8) in Biskinis and Fardis

$M_y = \min(M_{y\_ten}, M_{y\_com}) = 2.8606E+008$   
 $\gamma ((10a) \text{ or } (10b)) = 1.6206348E-005$   
 $M_{y\_ten} (8a) = 2.8606E+008$   
 $\gamma_{ten} (7a) = 73.23937$   
error of function (7a) = 0.00140752  
 $M_{y\_com} (8b) = 4.0293E+008$   
 $\gamma_{com} (7b) = 68.98129$   
error of function (7b) = -0.00043134  
with  $e_y = 0.002625$   
 $e_{co} = 0.002$   
 $a_{pl} = 0.45 ((9c) \text{ in Biskinis and Fardis for FRP Wrap})$   
 $d_1 = 44.00$   
 $R = 200.00$   
 $v = 0.00134943$   
 $N = 4770.087$   
 $A_c = 125663.706$   
 $= 0.45352339$   
with  $f_c^* ((12.3), \text{ACI } 440) = 28.12975$   
 $f_c = 24.00$   
 $f_l = 1.3173$   
 $k = 1$   
Effective FRP thickness,  $t_f = N L^* t \cos(b_1) = 1.016$   
 $e_{fe} ((12.5) \text{ and } (12.7)) = 0.004$   
 $E_f = 64828.00$

#### Calculation of ratio $l_b/l_d$

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

#### - Calculation of $p$ -

From table 10-9:  $p = 0.05310967$

with:

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

shear control ratio  $V_y E / V_{co} I_{OE} = 0.48361756$

$d = 0.00$

$s = 0.00$

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

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

$d c = D - 2^* \text{cover} - \text{Hoop Diameter} = 340.00$

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

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

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

$N U D = 4770.087$

$A_g = 125663.706$

$f_{cE} = 24.00$

$f_{yE} = f_{yI} = 525.00$

$p_l = \text{Area\_Tot\_Long\_Rein} / (A_g) = 0.0243$

$f_{cE} = 24.00$

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

At local axis: 3

Integration Section: (b)