

# Detailed Member Calculations

**Units: N&mm**

**Regulation: ASCE 41-17**

## Calculation No. 1

column C1, Floor 1

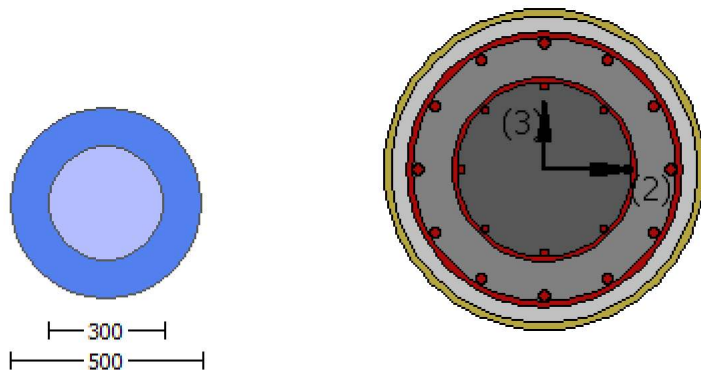
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JCC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcjcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 20.00$

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 25742.96$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
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, ASCE 41-17) because bending is considered as  
Deformation-Controlled Action (Table C7-1, ASCE 41-17).  
Jacket  
New material: Concrete Strength,  $f_c = f_{cm} = 30.00$   
New material: Steel Strength,  $f_s = f_{sm} = 625.00$   
Existing Column  
Existing material: Concrete Strength,  $f_c = f_{cm} = 24.00$   
Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$   
#####  
External Diameter,  $D = 500.00$   
Internal Diameter,  $D = 300.00$   
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,  $R = 40.00$   
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#### Stepwise Properties

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EDGE -A-  
Bending Moment,  $M_a = -1.7492E+007$   
Shear Force,  $V_a = -5829.318$   
EDGE -B-  
Bending Moment,  $M_b = 0.12862757$   
Shear Force,  $V_b = 5829.318$   
BOTH EDGES  
Axial Force,  $F = -7386.882$   
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:  $As_{c,com} = 1017.876$   
-Middle:  $As_{mid} = 1017.876$   
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 18.00$   
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Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = *V_n = 444663.668$   
 $V_n$  ((10.3), ASCE 41-17) =  $knI*V_{ColO} = 444663.668$   
 $V_{Col} = 444663.668$   
 $knI = 1.00$

displacement\_ductility\_demand = 0.01087845

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)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 18.56$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.7492 \times 10^7$

$V_u = 5829.318$

$d = 0.8 \cdot D = 400.00$

$N_u = 7386.882$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 246740.11$

$V_{s1} = 246740.11$  is calculated for jacket, with:

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

$f_y = 500.00$

$s = 100.00$

$V_{s1}$  is multiplied by  $\text{Col1} = 1.00$

$s/d = 0.25$

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

$A_v = A_{\text{stirrup}} / 2 = 78956.835$

$f_y = 420.00$

$s = 250.00$

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

$s/d = 1.04167$

$V_f$  ((11-3)-(11.4), ACI 440) = 247653.332

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, \alpha_1)|)$ , with:

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 470.00

$f_{fe}$  ((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:  $V_s + V_f \leq 359638.026$

$b_w \cdot d = A_v \cdot d / 4 = 125663.706$

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

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

From analysis, chord rotation  $\phi = 0.00020609$

$y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.0189444$  ((4.29), Biskinis Phd))

$M_y = 4.4260 \times 10^8$

$L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 3000.779

From table 10.5, ASCE 41\_17:  $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 2.3369 \times 10^{13}$

factor = 0.30

$A_g = 196349.541$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$

$N = 7386.882$

$E_c \cdot I_g = E_c \cdot I_{g_{\text{jacket}}} + E_c \cdot I_{g_{\text{core}}} = 7.7898 \times 10^{13}$

Calculation of Yielding Moment  $M_y$

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

$M_y = \min(M_{y\_ten}, M_{y\_com}) = 4.4260E+008$   
 $\phi_y ((10a) \text{ or } (10b)) = 1.3430728E-005$   
 $M_{y\_ten} (8a) = 4.4260E+008$   
 $\phi_{y\_ten} (7a) = 65.19069$   
error of function (7a) = 0.00234594  
 $M_{y\_com} (8b) = 7.6083E+008$   
 $\phi_{y\_com} (7b) = 64.49916$   
error of function (7b) = -0.00733981  
with  $e_y = 0.003125$   
 $e_{co} = 0.002$   
 $a_{pl} = 0.45$  ((9c) in Biskinis and Fardis for FRP Wrap)  
 $d_1 = 44.00$   
 $R = 250.00$   
 $v = 0.00112963$   
 $N = 7386.882$   
 $A_c = 196349.541$   
 $= 0.29185858$   
with  $f_c^*$  ((12.3), ACI 440) = 33.3038  
 $f_c = 30.00$   
 $f_l = 1.05384$   
 $k = 1$   
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  $l_b/l_d$

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

End Of Calculation of Shear Capacity for element: column JCC1 of floor 1

At local axis: 2

Integration Section: (a)

## Calculation No. 2

column C1, Floor 1

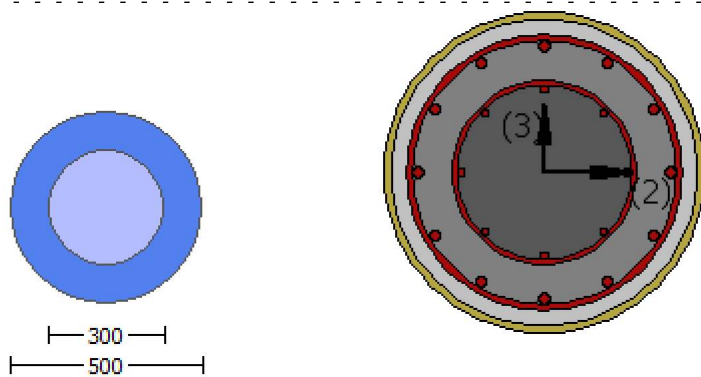
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\phi_u$ )

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 781.25$

Existing Column

Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.50688

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,  $ef_u = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $bi: 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

## Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 4.1010657E-031$

EDGE -B-

Shear Force,  $V_b = -4.1010657E-031$

BOTH EDGES

Axial Force,  $F = -7389.214$

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,  $V_e/V_r = 0.45961884$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 4.4703E+008$

$Mu_{1+} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 4.4703E+008$

$Mu_{2+} = 4.4703E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 4.4703E+008$ , 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),  $M_u$

$M_u = 4.4703E+008$

$= 0.97738438$

$' = 0.86668818$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TDY:  $f_{cc} = f_c^* \quad c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 781.25$

$l_b/l_d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$Ac = 196349.541$

$= \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.36292832$

Calculation of ratio  $l_b/l_d$

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

Calculation of  $Mu_{1-}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TDY: fcc = fc\* c = 45.20626  
conf. factor c = 1.50688  
fc = 30.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25  
lb/d = 1.00  
d1 = 44.00  
R = 250.00  
v = 0.00112412  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.36292832

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 = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TDY: fcc = fc\* c = 45.20626  
conf. factor c = 1.50688  
fc = 30.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25  
lb/d = 1.00  
d1 = 44.00  
R = 250.00  
v = 0.00112412  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.36292832

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 = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TDY: fcc = fc\* c = 45.20626

conf. factor  $c = 1.50688$   
 $f_c = 30.00$   
 From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 250.00$   
 $v = 0.00112412$   
 $N = 7389.214$   
 $A_c = 196349.541$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$

Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 648405.308$

Calculation of Shear Strength at edge 1,  $V_{r1} = 648405.308$

$V_{r1} = V_{Co1}$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{Co1}$

$V_{Co1} = 648405.308$

$k_{nl} = 1$  (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)

Mean concrete strength:  $f'_c = (f'_c_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f'_c_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f_c^{0.5} \leq 8.3$  MPa ((22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.1425332E-011$

$\nu_u = 4.1010657E-031$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From ((11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$f_y = 625.00$

$s = 100.00$

$V_{s1}$  is multiplied by  $\text{Col1} = 1.00$

$s/d = 0.25$

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

$A_v = \pi/2 \cdot A_{\text{stirrup}} = 78956.835$

$f_y = 525.00$

$s = 250.00$

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

$s/d = 1.04167$

$V_f$  ((11-3)-(11.4), ACI 440) = 247653.332

$f = 0.95$ , 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,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 470.00

$f_{fe}$  ((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:  $V_s + V_f \leq 440464.828$



$$b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 125663.706$$

Calculation of Shear Strength at edge 2,  $V_{r2} = 648405.308$

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

$$V_{Col0} = 648405.308$$

$k_{nl} = 1$  (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)

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.84$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M / Vd = 2.00$$

$$\mu_u = 2.1425332E-011$$

$$\nu_u = 4.1010657E-031$$

$$d = 0.8 \cdot D = 400.00$$

$$N_u = 7389.214$$

$$A_g = 196349.541$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$$f_y = 625.00$$

$$s = 100.00$$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$$s/d = 0.25$$

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

$$A_v = \frac{1}{2} \cdot A_{stirrup} = 78956.835$$

$$f_y = 525.00$$

$$s = 250.00$$

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

$$s/d = 1.04167$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 247653.332$$

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

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

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 470.00$$

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

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

From (11-11), ACI 440:  $V_s + V_f \leq 440464.828$

$$b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 125663.706$$

End Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjcs

Constant Properties

Knowledge Factor,  $\phi = 1.00$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 781.25$

Existing Column

Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.50688

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,  $ef_u = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $bi: 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

-----

Stepwise Properties

-----

At local axis: 2

EDGE -A-

Shear Force,  $V_a = -2.5110955E-047$

EDGE -B-

Shear Force,  $V_b = 2.5110955E-047$

BOTH EDGES

Axial Force,  $F = -7389.214$

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,  $V_e/V_r = 0.45961884$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$

with

$$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 4.4703\text{E}+008$$

$M_{u1+} = 4.4703\text{E}+008$ , 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

$M_{u1-} = 4.4703\text{E}+008$ , 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

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 4.4703\text{E}+008$$

$M_{u2+} = 4.4703\text{E}+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 4.4703\text{E}+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $M_{u1+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $M_u$   
 $M_u = 4.4703\text{E}+008$

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TDY:  $f_{cc} = f_c \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$$f_c = 30.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

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),  $M_u$   
 $M_u = 4.4703\text{E}+008$

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TDY:  $f_{cc} = f_c \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$$f_c = 30.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

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 = 4.4703E+008

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY:  $f_{cc} = f_c^* c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y * \text{Min}(1, 1.25 * (l_b / d)^{2/3}) = 781.25$

$$l_b / d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= * \text{Min}(1, 1.25 * (l_b / d)^{2/3}) = 0.36292832$$

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 = 4.4703E+008

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY:  $f_{cc} = f_c^* c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y * \text{Min}(1, 1.25 * (l_b / d)^{2/3}) = 781.25$

$$l_b / d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= * \text{Min}(1, 1.25 * (l_b / d)^{2/3}) = 0.36292832$$

Calculation of ratio  $l_b / d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 648405.308$

Calculation of Shear Strength at edge 1,  $V_{r1} = 648405.308$

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

$$V_{ColO} = 648405.308$$

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)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$f_y = 625.00$

$s = 100.00$

$V_{s1}$  is multiplied by  $\text{Col1} = 1.00$

$s/d = 0.25$

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

$A_v = \pi/2 \cdot A_{\text{stirrup}} = 78956.835$

$f_y = 525.00$

$s = 250.00$

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

$s/d = 1.04167$

$V_f$  ((11-3)-(11.4), ACI 440) = 247653.332

$f = 0.95$ , 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:  $\theta_1 = b_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 470.00

$f_{fe}$  ((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:  $V_s + V_f \leq 440464.828$

$b_w \cdot d = \pi \cdot d^2 / 4 = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 648405.308$

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

$V_{\text{Col0}} = 648405.308$

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)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$f_y = 625.00$

$s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s2}$  is multiplied by  $Col2 = 0.00$   
 $s/d = 1.04167$   
 $V_f ((11-3)-(11.4), ACI 440) = 247653.332$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 470.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 440464.828$   
 $b_w \cdot d = \sqrt{V_s + V_f} \cdot d / 4 = 125663.706$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1  
 At local axis: 2  
 -----

-----  
 Start Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1  
 At local axis: 2  
 Integration Section: (a)  
 Section Type: rcjcs

Constant Properties

-----  
 Knowledge Factor,  $K = 1.00$   
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.  
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
 Concrete Elasticity,  $E_c = 25742.96$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 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,  $E_s = 200000.00$   
 External Diameter,  $D = 500.00$   
 Internal Diameter,  $D = 300.00$   
 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,  $N_{oDir} = 1$

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = 7.9133033E-010$

Shear Force,  $V_2 = -5829.318$

Shear Force,  $V_3 = -2.1004643E-013$

Axial Force,  $F = -7386.882$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{sl,t} = 1272.345$

-Compression:  $A_{sl,c} = 1781.283$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Mean Diameter of Tension Reinforcement,  $D_bL = 18.00$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = u = 0.01446974$

$u = y + p = 0.01446974$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00946974$  ((4.29), Biskinis Phd))

$M_y = 4.4260E+008$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.3369E+013$

factor = 0.30

$A_g = 196349.541$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.84$

$N = 7386.882$

$E_c * I_g = E_c_{jacket} * I_{g,jacket} + E_c_{core} * I_{g,core} = 7.7898E+013$

#### Calculation of Yielding Moment $M_y$

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

$M_y = \min(M_{y,ten}, M_{y,com}) = 4.4260E+008$

$y$  ((10a) or (10b)) = 1.3430728E-005

$M_{y,ten}$  (8a) = 4.4260E+008

$y_{ten}$  (7a) = 65.19069

error of function (7a) = 0.00234594

$M_{y,com}$  (8b) = 7.6083E+008

$y_{com}$  (7b) = 64.49916

error of function (7b) = -0.00733981

with  $e_y = 0.003125$

$e_{co} = 0.002$

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

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112963$

$N = 7386.882$

$A_c = 196349.541$

$= 0.29185858$   
 with  $f_c^*$  ((12.3), ACI 440) = 33.3038  
 $f_c = 30.00$   
 $f_l = 1.05384$   
 $k = 1$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $e_{fe}$  ((12.5) and (12.7)) = 0.004  
 $E_f = 64828.00$

Calculation of ratio  $l_b/l_d$

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

- Calculation of  $p$  -

From table 10-9:  $p = 0.005$

with:

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

shear control ratio  $V_y E / V_{col} O E = 0.45961884$

$d = d_{external} = 0.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00660658$

jacket:  $s_1 = A_{v1} \cdot (D_{c1} / 2) / (s_1 \cdot A_g) = 0.0027646$

$A_{v1} = 78.53982$ , is the area of stirrup

$D_{c1} = D_{ext} - 2 \cdot cover - \text{External Hoop Diameter} = 440.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2} \cdot (D_{c2} / 2) / (s_2 \cdot A_g) = 0.00046968$

$A_{v2} = 50.26548$ , is the area of stirrup

$D_{c2} = D_{int} - \text{Internal Hoop Diameter} = 292.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

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.

For the normalisation  $f_s$  of jacket is used.

$N_{UD} = 7386.882$

$A_g = 196349.541$

$f_{cE} = (f_{c,jacket} \cdot \text{Area}_{jacket} + f_{c,core} \cdot \text{Area}_{core}) / \text{section\_area} = 27.84$

$f_{yLE} = (f_{y,ext\_Long\_Reinf} \cdot \text{Area}_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} \cdot \text{Area}_{int\_Long\_Reinf}) / \text{Area}_{Tot\_Long\_Rein} = 21219958E-314$

$f_{yTE} = (f_{y,ext\_Trans\_Reinf} \cdot \text{Area}_{ext\_Trans\_Reinf} + f_{y,int\_Trans\_Reinf} \cdot \text{Area}_{int\_Trans\_Reinf}) / \text{Area}_{Tot\_Trans\_Rein} = 610.4781$

$p_l = \text{Area}_{Tot\_Long\_Rein} / (A_g) = 0.015552$

$f_{cE} = 27.84$

End Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1

At local axis: 2

Integration Section: (a)

## Calculation No. 3



column C1, Floor 1

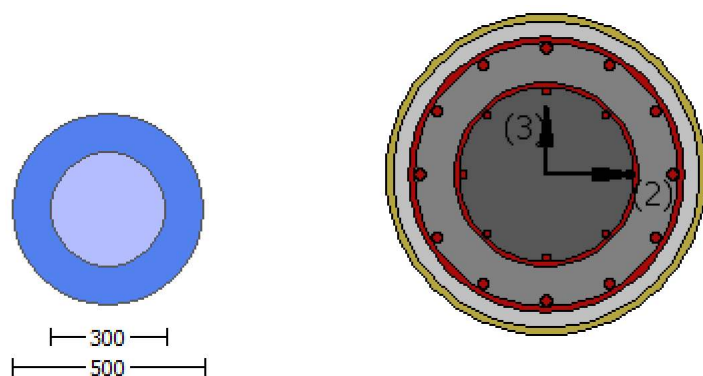
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JCC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 20.00$

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

Jacket

New material: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material: Steel Strength,  $f_s = f_{sm} = 625.00$

Existing Column

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

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

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

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,  $ε_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i: 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

EDGE -A-  
 Bending Moment,  $M_a = 7.9133033E-010$   
 Shear Force,  $V_a = -2.1004643E-013$   
 EDGE -B-  
 Bending Moment,  $M_b = -1.6094518E-010$   
 Shear Force,  $V_b = 2.1004643E-013$   
 BOTH EDGES  
 Axial Force,  $F = -7386.882$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{sl,t} = 1272.345$   
   -Compression:  $A_{sl,c} = 1781.283$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{sl,ten} = 1017.876$   
   -Compression:  $A_{sl,com} = 1017.876$   
   -Middle:  $A_{sl,mid} = 1017.876$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = V_n = 529689.31$   
 $V_n ((10.3), ASCE 41-17) = k_n \cdot V_{CoI0} = 529689.31$   
 $V_{CoI} = 529689.31$   
 $k_n = 1.00$   
 $displacement\_ductility\_demand = 0.00$

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

$= 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_c\_jacket \cdot Area\_jacket + f'_c\_core \cdot Area\_core) / Area\_section = 18.56$ , but  $f'_c^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 7.9133033E-010$   
 $V_u = 2.1004643E-013$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7386.882$   
 $A_g = 196349.541$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 246740.11$   
 $V_{s1} = 246740.11$  is calculated for jacket, with:  
 $A_v = A_{stirrup} / 2 = 123370.055$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = A_{stirrup} / 2 = 78956.835$   
 $f_y = 420.00$   
 $s = 250.00$

$V_{s2}$  is multiplied by  $Col2 = 0.00$   
 $s/d = 1.04167$   
 $V_f((11-3)-(11.4), ACI 440) = 247653.332$   
 $f = 0.95$ , 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:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL * t / NoDir = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 470.00  
 $f_{fe}((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 359638.026$   
 $bw * d = \rho * d^2 / 4 = 125663.706$

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  $\theta = 1.1135440E-020$   
 $y = (M_y * L_s / 3) / E_{eff} = 0.00946974$  ((4.29), Biskinis Phd))  
 $M_y = 4.4260E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 1500.00  
 From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} * E_c * I_g = 2.3369E+013$   
 $\text{factor} = 0.30$   
 $A_g = 196349.541$   
 Mean concrete strength:  $f'_c = (f'_c_{\text{jacket}} * \text{Area}_{\text{jacket}} + f'_c_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$   
 $N = 7386.882$   
 $E_c * I_g = E_{c_{\text{jacket}}} * I_{g_{\text{jacket}}} + E_{c_{\text{core}}} * I_{g_{\text{core}}} = 7.7898E+013$

Calculation of Yielding Moment  $M_y$

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

$M_y = \text{Min}(M_{y_{\text{ten}}}, M_{y_{\text{com}}}) = 4.4260E+008$   
 $y$  ((10a) or (10b)) = 1.3430728E-005  
 $M_{y_{\text{ten}}} (8a) = 4.4260E+008$   
 $\delta_{\text{ten}} (7a) = 65.19069$   
 error of function (7a) = 0.00234594  
 $M_{y_{\text{com}}} (8b) = 7.6083E+008$   
 $\delta_{\text{com}} (7b) = 64.49916$   
 error of function (7b) = -0.00733981  
 with  $e_y = 0.003125$   
 $e_{co} = 0.002$   
 $a_{pl} = 0.45$  ((9c) in Biskinis and Fardis for FRP Wrap)  
 $d1 = 44.00$   
 $R = 250.00$   
 $v = 0.00112963$   
 $N = 7386.882$   
 $A_c = 196349.541$   
 $= 0.29185858$   
 with  $f'_c$  ((12.3), ACI 440) = 33.3038  
 $f_c = 30.00$   
 $f_l = 1.05384$   
 $k = 1$   
 Effective FRP thickness,  $tf = NL * t * \cos(b1) = 1.016$   
 $e_{fe}((12.5) \text{ and } (12.7)) = 0.004$

Ef = 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 JCC1 of floor 1

At local axis: 3

Integration Section: (a)

## Calculation No. 4

column C1, Floor 1

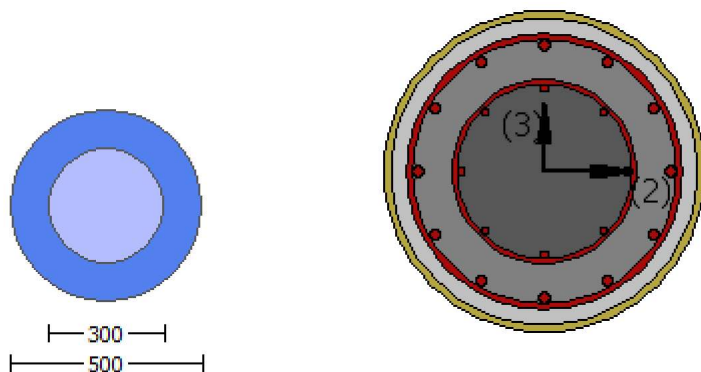
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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  
Jacket  
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 781.25$   
Existing Column  
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
#####  
External Diameter,  $D = 500.00$   
Internal Diameter,  $D = 300.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.50688  
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,  $V_a = 4.1010657E-031$   
EDGE -B-  
Shear Force,  $V_b = -4.1010657E-031$   
BOTH EDGES  
Axial Force,  $F = -7389.214$   
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,  $V_e/V_r = 0.45961884$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$   
with  
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 4.4703E+008$   
 $\mu_{u1+} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction  
which is defined for the static loading combination  
 $\mu_{u1-} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment  
direction which is defined for the static loading combination  
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 4.4703E+008$   
 $\mu_{u2+} = 4.4703E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction  
which is defined for the the static loading combination

Mu2- = 4.4703E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu1+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TDY: fcc = fc\* c = 45.20626  
conf. factor c = 1.50688  
fc = 30.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25  
lb/d = 1.00  
d1 = 44.00  
R = 250.00  
v = 0.00112412  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.36292832

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 = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TDY: fcc = fc\* c = 45.20626  
conf. factor c = 1.50688  
fc = 30.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25  
lb/d = 1.00  
d1 = 44.00  
R = 250.00  
v = 0.00112412  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.36292832

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

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

$$\mu_u = 4.4703E+008$$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TB DY:  $f_{cc} = f_c' \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_u$ -

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

$$\mu_u = 4.4703E+008$$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TB DY:  $f_{cc} = f_c' \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 648405.308$

Calculation of Shear Strength at edge 1,  $V_{r1} = 648405.308$

$V_{r1} = V_{c1}$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{c10}$

$V_{c10} = 648405.308$

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

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

$= 1$  (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$   
 $\mu_u = 2.1425332E-011$   
 $\mu_v = 4.1010657E-031$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7389.214$   
 $A_g = 196349.541$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$   
 $V_{s1} = 308425.138$  is calculated for jacket, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $\text{Col1} = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s2}$  is multiplied by  $\text{Col2} = 0.00$   
 $s/d = 1.04167$   
 $V_f ((11-3)-(11.4), \text{ACI 440}) = 247653.332$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 470.00  
 $f_{fe} ((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 440464.828$   
 $b_w \cdot d = \sqrt{4} \cdot d \cdot d / 4 = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 648405.308$   
 $V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE 41-17}) = k_n l \cdot V_{\text{Col0}}$   
 $V_{\text{Col0}} = 648405.308$   
 $k_n l = 1$  (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).

$\gamma_c = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_c \cdot \text{Area}_{\text{jacket}} + f'_c \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f'_c^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 2.1425332E-011$   
 $\mu_v = 4.1010657E-031$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7389.214$   
 $A_g = 196349.541$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$   
 $V_{s1} = 308425.138$  is calculated for jacket, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $\text{Col1} = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s2}$  is multiplied by  $\text{Col2} = 0.00$



$s/d = 1.04167$   
 $V_f((11-3)-(11.4), \text{ACI 440}) = 247653.332$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 470.00  
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 440464.828$   
 $b_w \cdot d = \frac{V_s \cdot d}{4} = 125663.706$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1  
 At local axis: 3  
 -----

-----  
 Start Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1  
 At Shear local axis: 2  
 (Bending local axis: 3)  
 Section Type: rcjcs

Constant Properties

-----  
 Knowledge Factor,  $\phi = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
 Concrete Elasticity,  $E_c = 25742.96$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 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  
 Jacket  
 New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 781.25$   
 Existing Column  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
 #####  
 External Diameter,  $D = 500.00$   
 Internal Diameter,  $D = 300.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.50688  
 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,  $V_a = -2.5110955E-047$

EDGE -B-

Shear Force,  $V_b = 2.5110955E-047$

BOTH EDGES

Axial Force,  $F = -7389.214$

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,  $V_e/V_r = 0.45961884$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$   
with

$M_{pr1} = \max(\mu_{1+}, \mu_{1-}) = 4.4703E+008$

$\mu_{1+} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{1-} = 4.4703E+008$ , 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

$M_{pr2} = \max(\mu_{2+}, \mu_{2-}) = 4.4703E+008$

$\mu_{2+} = 4.4703E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 4.4703E+008$ , 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),  $\mu_u$

$\mu_u = 4.4703E+008$

$\phi = 0.97738438$

$\phi' = 0.86668818$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TDY:  $f_{cc} = f_c' \quad c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \min(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

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),  $\mu$   
 $\mu = 4.4703\text{E}+008$

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

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),  $\mu$   
 $\mu = 4.4703\text{E}+008$

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

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 = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TBDY:  $f_{cc} = f_c' \cdot c = 45.20626$   
conf. factor  $c = 1.50688$   
 $f_c = 30.00$   
From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 250.00$   
 $v = 0.00112412$   
 $N = 7389.214$   
 $A_c = 196349.541$   
=  $\cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$

## Calculation of ratio $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 648405.308$

Calculation of Shear Strength at edge 1,  $V_{r1} = 648405.308$

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

$V_{CoI0} = 648405.308$

$k_{nl} = 1$  (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)  
Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f_c'^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 2.0093280E-011$   
 $\mu_v = 2.5110955E-047$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7389.214$   
 $A_g = 196349.541$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$   
 $V_{s1} = 308425.138$  is calculated for jacket, with:  
 $A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 123370.055$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $\text{Col1} = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 78956.835$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s2}$  is multiplied by  $\text{Col2} = 0.00$   
 $s/d = 1.04167$   
 $V_f \text{ ((11-3)-(11.4), ACI 440)} = 247653.332$   
 $f = 0.95$ , 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) = 470.00

$f_{fe}$  ((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:  $V_s + V_f \leq 440464.828$

$b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 648405.308$

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

$V_{Col0} = 648405.308$

$k_{nl} = 1$  (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).

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

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$f_y = 625.00$

$s = 100.00$

$V_{s1}$  is multiplied by  $\phi_{Col1} = 1.00$

$s/d = 0.25$

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

$A_v = \frac{1}{2} \cdot A_{\text{stirrup}} = 78956.835$

$f_y = 525.00$

$s = 250.00$

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

$s/d = 1.04167$

$V_f$  ((11-3)-(11.4), ACI 440) = 247653.332

$f = 0.95$ , 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  $\theta_i$ , 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) = 470.00

$f_{fe}$  ((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:  $V_s + V_f \leq 440464.828$

$b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 125663.706$

End Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjcs

#### Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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,  $E_s = 200000.00$

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

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,  $N_{oDir} = 1$

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -1.7492E+007$

Shear Force,  $V_2 = -5829.318$

Shear Force,  $V_3 = -2.1004643E-013$

Axial Force,  $F = -7386.882$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 1272.345$

-Compression:  $As_c = 1781.283$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Mean Diameter of Tension Reinforcement,  $Db_L = 18.00$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = \gamma \cdot u = 0.0239444$

$u = \gamma \cdot u + p = 0.0239444$

- Calculation of  $\rho_y$  -

$$\rho_y = (M_y * L_s / 3) / E_{eff} = 0.0189444 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 4.4260E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 3000.779$$

$$\text{From table 10.5, ASCE 41-17: } E_{eff} = \text{factor} * E_c * I_g = 2.3369E+013$$

$$\text{factor} = 0.30$$

$$A_g = 196349.541$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * A_{\text{jacket}} + f_c'_{\text{core}} * A_{\text{core}}) / A_{\text{section}} = 27.84$$

$$N = 7386.882$$

$$E_c * I_g = E_{c_{\text{jacket}}} * I_{g_{\text{jacket}}} + E_{c_{\text{core}}} * I_{g_{\text{core}}} = 7.7898E+013$$

Calculation of Yielding Moment  $M_y$

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

$$M_y = \text{Min}(M_{y_{\text{ten}}}, M_{y_{\text{com}}}) = 4.4260E+008$$

$$\rho_y \text{ ((10a) or (10b))} = 1.3430728E-005$$

$$M_{y_{\text{ten}}} \text{ (8a)} = 4.4260E+008$$

$$\rho_{y_{\text{ten}}} \text{ (7a)} = 65.19069$$

$$\text{error of function (7a)} = 0.00234594$$

$$M_{y_{\text{com}}} \text{ (8b)} = 7.6083E+008$$

$$\rho_{y_{\text{com}}} \text{ (7b)} = 64.49916$$

$$\text{error of function (7b)} = -0.00733981$$

$$\text{with } e_y = 0.003125$$

$$e_{co} = 0.002$$

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

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112963$$

$$N = 7386.882$$

$$A_c = 196349.541$$

$$= 0.29185858$$

$$\text{with } f_c' \text{ ((12.3), ACI 440)} = 33.3038$$

$$f_c = 30.00$$

$$f_l = 1.05384$$

$$k = 1$$

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

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

$$E_f = 64828.00$$

Calculation of ratio  $l_b/d$

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

- Calculation of  $\rho_p$  -

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

with:

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

$$\text{shear control ratio } V_y E / V_{co} I_{OE} = 0.45961884$$

$$d = d_{\text{external}} = 0.00$$

$$s = s_{\text{external}} = 0.00$$

$$t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00660658$$

$$\text{jacket: } s_1 = A_{v1} * ( \pi * D_c / 2 ) / ( s_1 * A_g ) = 0.0027646$$

$$A_{v1} = 78.53982, \text{ is the area of stirrup}$$

$$D_c1 = D_{\text{ext}} - 2 * \text{cover} - \text{External Hoop Diameter} = 440.00, \text{ is the total Length of all stirrups parallel to loading}$$

(shear) direction

$$s_1 = 100.00$$

$$\text{core: } s_2 = A_{v2} * ( \pi * D_c / 2 ) / ( s_2 * A_g ) = 0.00046968$$

$$A_{v2} = 50.26548, \text{ is the area of stirrup}$$

$$D_c2 = D_{\text{int}} - \text{Internal Hoop Diameter} = 292.00, \text{ is the total Length of all stirrups parallel to loading (shear)}$$

direction

$$s2 = 250.00$$

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.

For the normalisation  $f_s$  of jacket is used.

$$N_{UD} = 7386.882$$

$$A_g = 196349.541$$

$$f_{cE} = (f_{c\_jacket} \cdot Area\_jacket + f_{c\_core} \cdot Area\_core) / section\_area = 27.84$$

$$f_{yE} = (f_{y\_ext\_Long\_Reinf} \cdot Area\_ext\_Long\_Reinf + f_{y\_int\_Long\_Reinf} \cdot Area\_int\_Long\_Reinf) / Area\_Tot\_Long\_Rein = 21219958E-314$$

$$f_{yE} = (f_{y\_ext\_Trans\_Reinf} \cdot Area\_ext\_Trans\_Reinf + f_{y\_int\_Trans\_Reinf} \cdot Area\_int\_Trans\_Reinf) / Area\_Tot\_Trans\_Rein = 610.4781$$

$$p_l = Area\_Tot\_Long\_Rein / (A_g) = 0.015552$$

$$f_{cE} = 27.84$$

End Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1

At local axis: 3

Integration Section: (a)

## Calculation No. 5

column C1, Floor 1

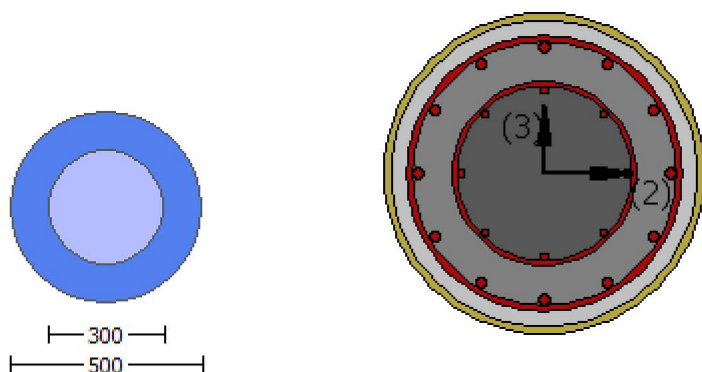
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JCC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rcjcs

Constant Properties



Knowledge Factor,  $\gamma = 1.00$   
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.  
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 20.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
Concrete Elasticity,  $E_c = 25742.96$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
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, ASCE 41-17) because bending is considered as  
Deformation-Controlled Action (Table C7-1, ASCE 41-17).  
Jacket  
New material: Concrete Strength,  $f_c = f_{cm} = 30.00$   
New material: Steel Strength,  $f_s = f_{sm} = 625.00$   
Existing Column  
Existing material: Concrete Strength,  $f_c = f_{cm} = 24.00$   
Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$   
#####  
External Diameter,  $D = 500.00$   
Internal Diameter,  $D = 300.00$   
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,  $ef_u = 0.01$   
Number of directions,  $NoDir = 1$   
Fiber orientations,  $bi: 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$   
-----

#### Stepwise Properties

-----  
EDGE -A-  
Bending Moment,  $M_a = -1.7492E+007$   
Shear Force,  $V_a = -5829.318$   
EDGE -B-  
Bending Moment,  $M_b = 0.12862757$   
Shear Force,  $V_b = 5829.318$   
BOTH EDGES  
Axial Force,  $F = -7386.882$   
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  $V_R = V_n = 529689.31$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n V_{Col0} = 529689.31$   
 $V_{Col} = 529689.31$   
 $k_n = 1.00$   
 $displacement\_ductility\_demand = 0.05927674$

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

$\lambda = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_c\_jacket \cdot Area\_jacket + f'_c\_core \cdot Area\_core) / Area\_section = 18.56$ , but  $f'_c^{0.5} \leq 8.3$  MPa ((22.5.3.1, ACI 318-14))  
 $M/Vd = 2.00$   
 $\mu_u = 0.12862757$   
 $V_u = 5829.318$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7386.882$   
 $A_g = 196349.541$   
 From ((11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 246740.11$   
 $V_{s1} = 246740.11$  is calculated for jacket, with:  
 $A_v = A_s / 2 \cdot A\_stirrup = 123370.055$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = A_s / 2 \cdot A\_stirrup = 78956.835$   
 $f_y = 420.00$   
 $s = 250.00$   
 $V_{s2}$  is multiplied by  $Col2 = 0.00$   
 $s/d = 1.04167$   
 $V_f$  ((11-3)-(11.4), ACI 440) =  $247653.332$   
 $f = 0.95$ , 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:  $\theta = 45^\circ$   
 $V_f = \min(|V_f(45, \theta)|, |V_f(-45, \theta)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{Dir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) =  $470.00$   
 $f_{fe}$  ((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:  $V_s + V_f \leq 359638.026$   
 $b_w \cdot d = V_u \cdot d / 4 = 125663.706$

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

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

From analysis, chord rotation  $\theta = 0.00011227$   
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00189395$  ((4.29), Biskinis Phd))  
 $M_y = 4.4260E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) =  $300.00$   
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 2.3369E+013$   
 $factor = 0.30$   
 $A_g = 196349.541$   
 Mean concrete strength:  $f'_c = (f'_c\_jacket \cdot Area\_jacket + f'_c\_core \cdot Area\_core) / Area\_section = 27.84$

$$N = 7386.882$$

$$Ec \cdot I_g = Ec_{jacket} \cdot I_{g\_jacket} + Ec_{core} \cdot I_{g\_core} = 7.7898E+013$$

Calculation of Yielding Moment  $M_y$

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

$$M_y = \min(M_{y\_ten}, M_{y\_com}) = 4.4260E+008$$

$$\rho_y ((10a) \text{ or } (10b)) = 1.3430728E-005$$

$$M_{y\_ten} (8a) = 4.4260E+008$$

$$\rho_{y\_ten} (7a) = 65.19069$$

$$\text{error of function (7a)} = 0.00234594$$

$$M_{y\_com} (8b) = 7.6083E+008$$

$$\rho_{y\_com} (7b) = 64.49916$$

$$\text{error of function (7b)} = -0.00733981$$

$$\text{with } e_y = 0.003125$$

$$e_{co} = 0.002$$

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

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112963$$

$$N = 7386.882$$

$$A_c = 196349.541$$

$$= 0.29185858$$

$$\text{with } f_c^* ((12.3), \text{ACI 440}) = 33.3038$$

$$f_c = 30.00$$

$$f_l = 1.05384$$

$$k = 1$$

$$\text{Effective FRP thickness, } t_f = N L^* t^* \cos(\theta_1) = 1.016$$

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

$$E_f = 64828.00$$

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 JCC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 6

column C1, Floor 1

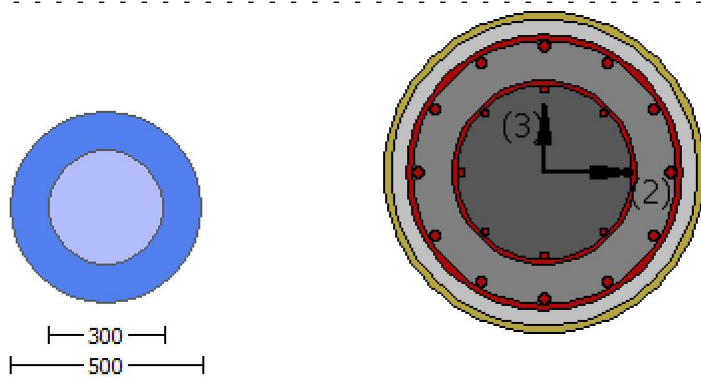
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\phi_r$ )

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 781.25$

Existing Column

Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.50688

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,  $efu = 0.01$

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,  $V_a = 4.1010657E-031$

EDGE -B-

Shear Force,  $V_b = -4.1010657E-031$

BOTH EDGES

Axial Force,  $F = -7389.214$

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,  $V_e/V_r = 0.45961884$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$   
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 4.4703E+008$

$\mu_{1+} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{1-} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 4.4703E+008$

$\mu_{2+} = 4.4703E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 4.4703E+008$ , 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),  $\mu_u$

$\mu_u = 4.4703E+008$

$\phi = 0.97738438$

$\phi' = 0.86668818$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TDY:  $f_{cc} = f_c^* \quad c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 781.25$

$l_b/l_d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

$= \phi \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.36292832$

Calculation of ratio  $l_b/l_d$

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

Calculation of  $\mu_{1-}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TDY: fcc = fc\* c = 45.20626  
conf. factor c = 1.50688  
fc = 30.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25  
lb/d = 1.00  
d1 = 44.00  
R = 250.00  
v = 0.00112412  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.36292832

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 = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TDY: fcc = fc\* c = 45.20626  
conf. factor c = 1.50688  
fc = 30.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25  
lb/d = 1.00  
d1 = 44.00  
R = 250.00  
v = 0.00112412  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.36292832

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 = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TDY: fcc = fc\* c = 45.20626

conf. factor  $c = 1.50688$   
 $f_c = 30.00$   
 From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 250.00$   
 $v = 0.00112412$   
 $N = 7389.214$   
 $A_c = 196349.541$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$

Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 648405.308$

Calculation of Shear Strength at edge 1,  $V_{r1} = 648405.308$

$V_{r1} = V_{Co1}$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{Co1}$

$V_{Co1} = 648405.308$

$k_{nl} = 1$  (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)

Mean concrete strength:  $f'_c = (f'_c_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f'_c_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f_c^{0.5} \leq 8.3$  MPa ((22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.1425332E-011$

$\nu_u = 4.1010657E-031$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From ((11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$f_y = 625.00$

$s = 100.00$

$V_{s1}$  is multiplied by  $\text{Col1} = 1.00$

$s/d = 0.25$

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

$A_v = \cdot /2 \cdot A_{\text{stirrup}} = 78956.835$

$f_y = 525.00$

$s = 250.00$

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

$s/d = 1.04167$

$V_f$  ((11-3)-(11.4), ACI 440) = 247653.332

$f = 0.95$ , 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  $\alpha$  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,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 470.00

$f_{fe}$  ((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:  $V_s + V_f \leq 440464.828$

$$b_w \cdot d = \frac{b \cdot d^2}{4} = 125663.706$$

Calculation of Shear Strength at edge 2,  $V_{r2} = 648405.308$

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

$$V_{Col0} = 648405.308$$

$k_{nl} = 1$  (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)

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.84$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M / Vd = 2.00$$

$$\mu_u = 2.1425332E-011$$

$$\nu_u = 4.1010657E-031$$

$$d = 0.8 \cdot D = 400.00$$

$$N_u = 7389.214$$

$$A_g = 196349.541$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$$f_y = 625.00$$

$$s = 100.00$$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$$s/d = 0.25$$

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

$$A_v = \frac{1}{2} \cdot A_{stirrup} = 78956.835$$

$$f_y = 525.00$$

$$s = 250.00$$

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

$$s/d = 1.04167$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 247653.332$$

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

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

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 470.00$$

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

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

From (11-11), ACI 440:  $V_s + V_f \leq 440464.828$

$$b_w \cdot d = \frac{b \cdot d^2}{4} = 125663.706$$

End Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjcs

Constant Properties

Knowledge Factor,  $\phi = 1.00$

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



Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 781.25$

Existing Column

Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.50688

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,  $ef_u = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $bi: 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

-----

Stepwise Properties

-----

At local axis: 2

EDGE -A-

Shear Force,  $V_a = -2.5110955E-047$

EDGE -B-

Shear Force,  $V_b = 2.5110955E-047$

BOTH EDGES

Axial Force,  $F = -7389.214$

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:  $As_{l,mid} = 1017.876$

-----

-----

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.45961884$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$

with

$$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 4.4703\text{E}+008$$

$M_{u1+} = 4.4703\text{E}+008$ , 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

$M_{u1-} = 4.4703\text{E}+008$ , 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

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 4.4703\text{E}+008$$

$M_{u2+} = 4.4703\text{E}+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 4.4703\text{E}+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $M_{u1+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $M_u$   
 $M_u = 4.4703\text{E}+008$

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TDY:  $f_{cc} = f_c \cdot c = 45.20626$

$$\text{conf. factor } c = 1.50688$$

$$f_c = 30.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

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),  $M_u$   
 $M_u = 4.4703\text{E}+008$

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TDY:  $f_{cc} = f_c \cdot c = 45.20626$

$$\text{conf. factor } c = 1.50688$$

$$f_c = 30.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

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 = 4.4703E+008

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: fcc = fc\* c = 45.20626

conf. factor c = 1.50688

fc = 30.00

From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25

$$lb/d = 1.00$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1,1.25*(lb/d)^ 2/3) = 0.36292832$$

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 = 4.4703E+008

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: fcc = fc\* c = 45.20626

conf. factor c = 1.50688

fc = 30.00

From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25

$$lb/d = 1.00$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1,1.25*(lb/d)^ 2/3) = 0.36292832$$

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 648405.308

Calculation of Shear Strength at edge 1, Vr1 = 648405.308

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

$$VColO = 648405.308$$

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)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$f_y = 625.00$

$s = 100.00$

$V_{s1}$  is multiplied by  $\text{Col1} = 1.00$

$s/d = 0.25$

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

$A_v = \pi/2 \cdot A_{\text{stirrup}} = 78956.835$

$f_y = 525.00$

$s = 250.00$

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

$s/d = 1.04167$

$V_f$  ((11-3)-(11.4), ACI 440) = 247653.332

$f = 0.95$ , 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:  $\theta_1 = b_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 470.00

$f_{fe}$  ((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:  $V_s + V_f \leq 440464.828$

$b_w \cdot d = \pi \cdot d^2 / 4 = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 648405.308$

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

$V_{\text{Col0}} = 648405.308$

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)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$f_y = 625.00$

$s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s2}$  is multiplied by  $Col2 = 0.00$   
 $s/d = 1.04167$   
 $V_f ((11-3)-(11.4), ACI 440) = 247653.332$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 470.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 440464.828$   
 $b_w \cdot d = \sqrt{V_s + V_f} \cdot d / 4 = 125663.706$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1  
 At local axis: 2  
 -----

Start Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1  
 At local axis: 2  
 Integration Section: (b)  
 Section Type: rcjcs

Constant Properties

-----  
 Knowledge Factor,  $\phi = 1.00$   
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.  
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
 Concrete Elasticity,  $E_c = 25742.96$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 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,  $E_s = 200000.00$   
 External Diameter,  $D = 500.00$   
 Internal Diameter,  $D = 300.00$   
 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,  $N_{oDir} = 1$

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -1.6094518E-010$

Shear Force,  $V_2 = 5829.318$

Shear Force,  $V_3 = 2.1004643E-013$

Axial Force,  $F = -7386.882$

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  $\phi_{u,R} = \phi_u = 0.01446974$

$\phi_u = \phi_y + \phi_p = 0.01446974$

- Calculation of  $\phi_y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00946974$  ((4.29), Biskinis Phd))

$M_y = 4.4260E+008$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.3369E+013$

factor = 0.30

$A_g = 196349.541$

Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 27.84$

$N = 7386.882$

$E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 7.7898E+013$

#### Calculation of Yielding Moment $M_y$

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

$M_y = \min(M_{y,ten}, M_{y,com}) = 4.4260E+008$

$y$  ((10a) or (10b)) = 1.3430728E-005

$M_{y,ten}$  (8a) = 4.4260E+008

$y_{ten}$  (7a) = 65.19069

error of function (7a) = 0.00234594

$M_{y,com}$  (8b) = 7.6083E+008

$y_{com}$  (7b) = 64.49916

error of function (7b) = -0.00733981

with  $e_y = 0.003125$

$e_{co} = 0.002$

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

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112963$

$N = 7386.882$

$A_c = 196349.541$

$= 0.29185858$   
 with  $f_c^*$  ((12.3), ACI 440) = 33.3038  
 $f_c = 30.00$   
 $f_l = 1.05384$   
 $k = 1$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $e_{fe}$  ((12.5) and (12.7)) = 0.004  
 $E_f = 64828.00$

Calculation of ratio  $l_b/l_d$

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

- Calculation of  $p$  -

From table 10-9:  $p = 0.005$

with:

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

shear control ratio  $V_y E / V_{col} O E = 0.45961884$

$d = d_{external} = 0.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00660658$

jacket:  $s_1 = A_{v1} \cdot (D_{c1} / 2) / (s_1 \cdot A_g) = 0.0027646$

$A_{v1} = 78.53982$ , is the area of stirrup

$D_{c1} = D_{ext} - 2 \cdot cover - \text{External Hoop Diameter} = 440.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2} \cdot (D_{c2} / 2) / (s_2 \cdot A_g) = 0.00046968$

$A_{v2} = 50.26548$ , is the area of stirrup

$D_{c2} = D_{int} - \text{Internal Hoop Diameter} = 292.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

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.

For the normalisation  $f_s$  of jacket is used.

$N_{UD} = 7386.882$

$A_g = 196349.541$

$f_{cE} = (f_{c,jacket} \cdot \text{Area}_{jacket} + f_{c,core} \cdot \text{Area}_{core}) / \text{section\_area} = 27.84$

$f_{yLE} = (f_{y,ext\_Long\_Reinf} \cdot \text{Area}_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} \cdot \text{Area}_{int\_Long\_Reinf}) / \text{Area}_{Tot\_Long\_Rein} = 21219958E-314$

$f_{yTE} = (f_{y,ext\_Trans\_Reinf} \cdot \text{Area}_{ext\_Trans\_Reinf} + f_{y,int\_Trans\_Reinf} \cdot \text{Area}_{int\_Trans\_Reinf}) / \text{Area}_{Tot\_Trans\_Rein} = 610.4781$

$p_l = \text{Area}_{Tot\_Long\_Rein} / (A_g) = 0.015552$

$f_{cE} = 27.84$

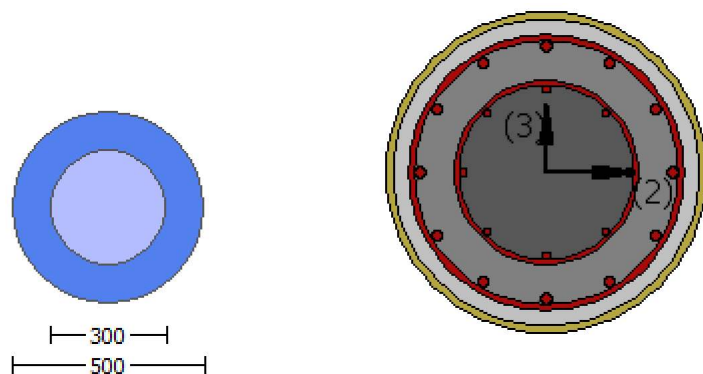
End Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1

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 VRd  
 Edge: End  
 Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JCC1 of floor 1  
 At local axis: 3  
 Integration Section: (b)  
 Section Type: rcjcs

#### Constant Properties

Knowledge Factor,  $\gamma = 1.00$   
 Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.  
 Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 20.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
 Concrete Elasticity,  $E_c = 25742.96$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 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, ASCE 41-17) because bending is considered as  
 Deformation-Controlled Action (Table C7-1, ASCE 41-17).  
 Jacket  
 New material: Concrete Strength,  $f_c = f_{cm} = 30.00$   
 New material: Steel Strength,  $f_s = f_{sm} = 625.00$   
 Existing Column  
 Existing material: Concrete Strength,  $f_c = f_{cm} = 24.00$   
 Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$   
 #####  
 External Diameter,  $D = 500.00$   
 Internal Diameter,  $D = 300.00$   
 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,  $N_{oDir} = 1$   
 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,  $M_a = 7.9133033E-010$   
 Shear Force,  $V_a = -2.1004643E-013$   
 EDGE -B-  
 Bending Moment,  $M_b = -1.6094518E-010$   
 Shear Force,  $V_b = 2.1004643E-013$   
 BOTH EDGES  
 Axial Force,  $F = -7386.882$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{sl,t} = 0.00$   
   -Compression:  $A_{sl,c} = 3053.628$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{sl,ten} = 1017.876$   
   -Compression:  $A_{sl,com} = 1017.876$   
   -Middle:  $A_{sl,mid} = 1017.876$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = V_n = 529689.31$   
 $V_n ((10.3), ASCE 41-17) = k_n l^* V_{CoI0} = 529689.31$   
 $V_{CoI} = 529689.31$   
 $k_n l = 1.00$   
 $displacement\_ductility\_demand = 0.00$

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)  
 Mean concrete strength:  $f'_c = (f'_c\_jacket * Area\_jacket + f'_c\_core * Area\_core) / Area\_section = 18.56$ , but  $f'_c^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.6094518E-010$   
 $V_u = 2.1004643E-013$   
 $d = 0.8 * D = 400.00$   
 $N_u = 7386.882$   
 $A_g = 196349.541$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 246740.11$   
 $V_{s1} = 246740.11$  is calculated for jacket, with:  
 $A_v = A_{stirrup} / 2 = 123370.055$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = A_{stirrup} / 2 = 78956.835$   
 $f_y = 420.00$   
 $s = 250.00$

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

$s/d = 1.04167$

$V_f((11-3)-(11.4), ACI 440) = 247653.332$

$f = 0.95$ , 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:  $\theta = b1 + 90^\circ = 90.00$

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

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

$dfv = d$  (figure 11.2, ACI 440) = 470.00

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 359638.026$

$bw \cdot d = \rho \cdot d^2 / 4 = 125663.706$

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  $\theta = 6.6331167E-021$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00946974$  ((4.29), Biskinis Phd))

$M_y = 4.4260E+008$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 2.3369E+013$

factor = 0.30

$A_g = 196349.541$

Mean concrete strength:  $f'_c = (f'_c_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f'_c_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$

$N = 7386.882$

$E_c \cdot I_g = E_{c_{\text{jacket}}} \cdot I_{g_{\text{jacket}}} + E_{c_{\text{core}}} \cdot I_{g_{\text{core}}} = 7.7898E+013$

Calculation of Yielding Moment  $M_y$

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

$M_y = \text{Min}(M_{y_{\text{ten}}}, M_{y_{\text{com}}}) = 4.4260E+008$

$y$  ((10a) or (10b)) = 1.3430728E-005

$M_{y_{\text{ten}}} (8a) = 4.4260E+008$

$\delta_{\text{ten}} (7a) = 65.19069$

error of function (7a) = 0.00234594

$M_{y_{\text{com}}} (8b) = 7.6083E+008$

$\delta_{\text{com}} (7b) = 64.49916$

error of function (7b) = -0.00733981

with  $e_y = 0.003125$

$e_{co} = 0.002$

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

$d1 = 44.00$

$R = 250.00$

$v = 0.00112963$

$N = 7386.882$

$A_c = 196349.541$

$= 0.29185858$

with  $f'_c$  ((12.3), ACI 440) = 33.3038

$f_c = 30.00$

$f_l = 1.05384$

$k = 1$

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

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

Ef = 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 JCC1 of floor 1

At local axis: 3

Integration Section: (b)

## Calculation No. 8

column C1, Floor 1

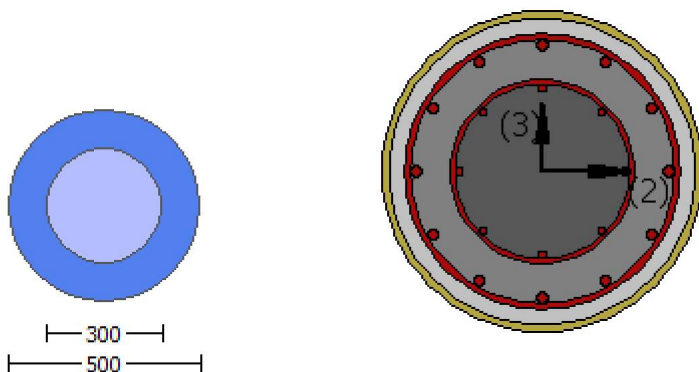
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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  
Jacket  
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 781.25$   
Existing Column  
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
#####  
External Diameter,  $D = 500.00$   
Internal Diameter,  $D = 300.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.50688  
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,  $V_a = 4.1010657E-031$   
EDGE -B-  
Shear Force,  $V_b = -4.1010657E-031$   
BOTH EDGES  
Axial Force,  $F = -7389.214$   
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,  $V_e/V_r = 0.45961884$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$   
with  
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 4.4703E+008$   
 $\mu_{u1+} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction  
which is defined for the static loading combination  
 $\mu_{u1-} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment  
direction which is defined for the static loading combination  
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 4.4703E+008$   
 $\mu_{u2+} = 4.4703E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction  
which is defined for the the static loading combination

Mu2- = 4.4703E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu1+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TBDY: fcc = fc\* c = 45.20626  
conf. factor c = 1.50688  
fc = 30.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25  
lb/d = 1.00  
d1 = 44.00  
R = 250.00  
v = 0.00112412  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.36292832

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 = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TBDY: fcc = fc\* c = 45.20626  
conf. factor c = 1.50688  
fc = 30.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25  
lb/d = 1.00  
d1 = 44.00  
R = 250.00  
v = 0.00112412  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.36292832

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

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

$$\mu_u = 4.4703E+008$$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TB DY:  $f_{cc} = f_c \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_u$ -

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

$$\mu_u = 4.4703E+008$$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TB DY:  $f_{cc} = f_c \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 648405.308$

Calculation of Shear Strength at edge 1,  $V_{r1} = 648405.308$

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

$V_{c0} = 648405.308$

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

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

$= 1$  (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_c \cdot \text{jacket} \cdot \text{Area}_{\text{jacket}} + f'_c \cdot \text{core} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$   
 $\mu_u = 2.1425332E-011$   
 $\mu_v = 4.1010657E-031$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7389.214$   
 $A_g = 196349.541$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$   
 $V_{s1} = 308425.138$  is calculated for jacket, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s2}$  is multiplied by  $Col2 = 0.00$   
 $s/d = 1.04167$   
 $V_f ((11-3)-(11.4), ACI 440) = 247653.332$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 470.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 440464.828$   
 $b_w \cdot d = \sqrt{4} \cdot d \cdot d / 4 = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 648405.308$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{Col0}$   
 $V_{Col0} = 648405.308$   
 $knl = 1$  (zero step-static loading)

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

$\gamma_c = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_c \cdot A_{jacket} + f'_c \cdot A_{core}) / A_{section} = 27.84$ , but  $f'_c^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 2.1425332E-011$   
 $\mu_v = 4.1010657E-031$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7389.214$   
 $A_g = 196349.541$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$   
 $V_{s1} = 308425.138$  is calculated for jacket, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s2}$  is multiplied by  $Col2 = 0.00$

$s/d = 1.04167$   
 $V_f((11-3)-(11.4), \text{ACI 440}) = 247653.332$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = NL \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 470.00  
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 440464.828$   
 $b_w \cdot d = \frac{V_s \cdot d}{4} = 125663.706$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1  
 At local axis: 3  
 -----

-----  
 Start Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1  
 At Shear local axis: 2  
 (Bending local axis: 3)  
 Section Type: rcjcs

#### Constant Properties

-----  
 Knowledge Factor,  $\phi = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
 Concrete Elasticity,  $E_c = 25742.96$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 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  
 Jacket  
 New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 781.25$   
 Existing Column  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
 #####  
 External Diameter,  $D = 500.00$   
 Internal Diameter,  $D = 300.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.50688  
 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,  $V_a = -2.5110955E-047$

EDGE -B-

Shear Force,  $V_b = 2.5110955E-047$

BOTH EDGES

Axial Force,  $F = -7389.214$

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,  $V_e/V_r = 0.45961884$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$   
with

$M_{pr1} = \max(\mu_{1+}, \mu_{1-}) = 4.4703E+008$

$\mu_{1+} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{1-} = 4.4703E+008$ , 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

$M_{pr2} = \max(\mu_{2+}, \mu_{2-}) = 4.4703E+008$

$\mu_{2+} = 4.4703E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 4.4703E+008$ , 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),  $\mu_u$

$\mu_u = 4.4703E+008$

$\phi = 0.97738438$

$\phi' = 0.86668818$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TDY:  $f_{cc} = f_c^* \quad c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \min(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

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),  $\mu$   
 $\mu = 4.4703\text{E}+008$

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

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),  $\mu$   
 $\mu = 4.4703\text{E}+008$

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

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 = 4.4703E+008

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY:  $f_{cc} = f_c' \cdot c = 45.20626$

$$\text{conf. factor } c = 1.50688$$

$$f_c = 30.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 648405.308$

Calculation of Shear Strength at edge 1,  $V_{r1} = 648405.308$

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

$$V_{Co10} = 648405.308$$

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

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

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

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f_c'^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$\text{Mu} = 2.0093280\text{E-}011$$

$$\text{Vu} = 2.5110955\text{E-}047$$

$$d = 0.8 \cdot D = 400.00$$

$$N_u = 7389.214$$

$$A_g = 196349.541$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$$f_y = 625.00$$

$$s = 100.00$$

$V_{s1}$  is multiplied by  $\text{Col1} = 1.00$

$$s/d = 0.25$$

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

$$A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 78956.835$$

$$f_y = 525.00$$

$$s = 250.00$$

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

$$s/d = 1.04167$$

$V_f$  ((11-3)-(11.4), ACI 440) = 247653.332

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

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

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 470.00

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 440464.828$

$b_w * d = \rho * d * d / 4 = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 648405.308$

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

$V_{Col0} = 648405.308$

$k_{nl} = 1$  (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).

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

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 * D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$f_y = 625.00$

$s = 100.00$

$V_{s1}$  is multiplied by  $\text{Col1} = 1.00$

$s/d = 0.25$

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

$A_v = \rho / 2 * A_{\text{stirrup}} = 78956.835$

$f_y = 525.00$

$s = 250.00$

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

$s/d = 1.04167$

$V_f((11-3)-(11.4), \text{ACI 440}) = 247653.332$

$f = 0.95$ , 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  $\theta_i$ , 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,  $t_{f1} = N_L * t / \text{NoDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 470.00

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 440464.828$

$b_w * d = \rho * d * d / 4 = 125663.706$

End Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcjcs

#### Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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,  $E_s = 200000.00$

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

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,  $N_{oDir} = 1$

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = 0.12862757$

Shear Force,  $V_2 = 5829.318$

Shear Force,  $V_3 = 2.1004643E-013$

Axial Force,  $F = -7386.882$

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:  $As_{l,mid} = 1017.876$

Mean Diameter of Tension Reinforcement,  $Db_L = 18.00$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{R} = * u = 0.00689395$

$u = y + p = 0.00689395$

- Calculation of  $\rho_y$  -

$$\rho_y = (M_y * L_s / 3) / E_{eff} = 0.00189395 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 4.4260E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 300.00$$

$$\text{From table 10.5, ASCE 41-17: } E_{eff} = \text{factor} * E_c * I_g = 2.3369E+013$$

$$\text{factor} = 0.30$$

$$A_g = 196349.541$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * A_{\text{jacket}} + f_c'_{\text{core}} * A_{\text{core}}) / A_{\text{section}} = 27.84$$

$$N = 7386.882$$

$$E_c * I_g = E_{c_{\text{jacket}}} * I_{g_{\text{jacket}}} + E_{c_{\text{core}}} * I_{g_{\text{core}}} = 7.7898E+013$$

Calculation of Yielding Moment  $M_y$

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

$$M_y = \text{Min}(M_{y_{\text{ten}}}, M_{y_{\text{com}}}) = 4.4260E+008$$

$$\rho_y \text{ ((10a) or (10b))} = 1.3430728E-005$$

$$M_{y_{\text{ten}}} \text{ (8a)} = 4.4260E+008$$

$$\rho_{y_{\text{ten}}} \text{ (7a)} = 65.19069$$

$$\text{error of function (7a)} = 0.00234594$$

$$M_{y_{\text{com}}} \text{ (8b)} = 7.6083E+008$$

$$\rho_{y_{\text{com}}} \text{ (7b)} = 64.49916$$

$$\text{error of function (7b)} = -0.00733981$$

$$\text{with } e_y = 0.003125$$

$$e_{co} = 0.002$$

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

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112963$$

$$N = 7386.882$$

$$A_c = 196349.541$$

$$= 0.29185858$$

$$\text{with } f_c' \text{ ((12.3), ACI 440)} = 33.3038$$

$$f_c = 30.00$$

$$f_l = 1.05384$$

$$k = 1$$

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

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

$$E_f = 64828.00$$

Calculation of ratio  $l_b/d$

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

- Calculation of  $\rho_p$  -

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

with:

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

$$\text{shear control ratio } V_y E / V_{co} I_{OE} = 0.45961884$$

$$d = d_{\text{external}} = 0.00$$

$$s = s_{\text{external}} = 0.00$$

$$t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00660658$$

$$\text{jacket: } s_1 = A_{v1} * (d_c / 2) / (s_1 * A_g) = 0.0027646$$

$$A_{v1} = 78.53982, \text{ is the area of stirrup}$$

$$D_{c1} = D_{\text{ext}} - 2 * \text{cover} - \text{External Hoop Diameter} = 440.00, \text{ is the total Length of all stirrups parallel to loading}$$

(shear) direction

$$s_1 = 100.00$$

$$\text{core: } s_2 = A_{v2} * (d_c / 2) / (s_2 * A_g) = 0.00046968$$

$$A_{v2} = 50.26548, \text{ is the area of stirrup}$$

$$D_{c2} = D_{\text{int}} - \text{Internal Hoop Diameter} = 292.00, \text{ is the total Length of all stirrups parallel to loading (shear)}$$

direction

$$s2 = 250.00$$

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.

For the normalisation  $f_s$  of jacket is used.

$$N_{UD} = 7386.882$$

$$A_g = 196349.541$$

$$f_{cE} = (f_{c\_jacket} \cdot Area\_jacket + f_{c\_core} \cdot Area\_core) / section\_area = 27.84$$

$$f_{yE} = (f_{y\_ext\_Long\_Reinf} \cdot Area\_ext\_Long\_Reinf + f_{y\_int\_Long\_Reinf} \cdot Area\_int\_Long\_Reinf) / Area\_Tot\_Long\_Rein = 21219958E-314$$

$$f_{yE} = (f_{y\_ext\_Trans\_Reinf} \cdot Area\_ext\_Trans\_Reinf + f_{y\_int\_Trans\_Reinf} \cdot Area\_int\_Trans\_Reinf) / Area\_Tot\_Trans\_Rein = 610.4781$$

$$\rho_l = Area\_Tot\_Long\_Rein / (A_g) = 0.015552$$

$$f_{cE} = 27.84$$

End Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1

At local axis: 3

Integration Section: (b)

## Calculation No. 9

column C1, Floor 1

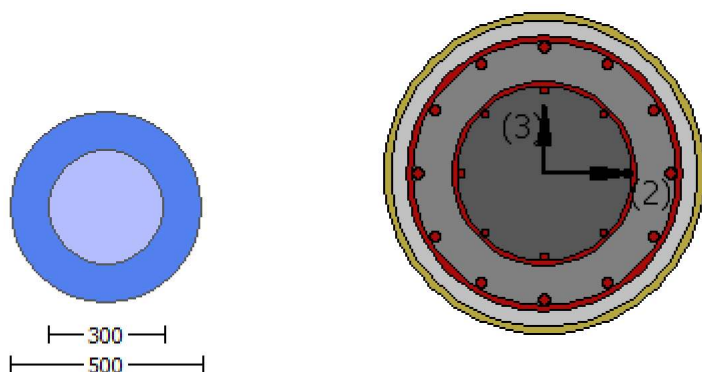
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JCC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcjcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$   
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.  
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 20.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
Concrete Elasticity,  $E_c = 25742.96$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
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, ASCE 41-17) because bending is considered as  
Deformation-Controlled Action (Table C7-1, ASCE 41-17).  
Jacket  
New material: Concrete Strength,  $f_c = f_{cm} = 30.00$   
New material: Steel Strength,  $f_s = f_{sm} = 625.00$   
Existing Column  
Existing material: Concrete Strength,  $f_c = f_{cm} = 24.00$   
Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$   
#####  
External Diameter,  $D = 500.00$   
Internal Diameter,  $D = 300.00$   
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,  $ef_u = 0.01$   
Number of directions,  $NoDir = 1$   
Fiber orientations,  $bi: 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$   
-----

#### Stepwise Properties

-----  
EDGE -A-  
Bending Moment,  $M_a = -1.4007E+007$   
Shear Force,  $V_a = -4667.709$   
EDGE -B-  
Bending Moment,  $M_b = 0.10299595$   
Shear Force,  $V_b = 4667.709$   
BOTH EDGES  
Axial Force,  $F = -7387.347$   
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  $V_R = V_n = 444663.714$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n V_{Col0} = 444663.714$   
 $V_{Col} = 444663.714$   
 $k_n = 1.00$   
 $displacement\_ductility\_demand = 0.0087107$

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)  
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 18.56$ , but  $f_c'^{0.5} \leq 8.3$  MPa ((22.5.3.1, ACI 318-14))  
 $M/Vd = 4.00$   
 $\mu_u = 1.4007E+007$   
 $V_u = 4667.709$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7387.347$   
 $A_g = 196349.541$   
 From ((11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 246740.11$   
 $V_{s1} = 246740.11$  is calculated for jacket, with:  
 $A_v = A_s / 2 \cdot A_{stirrup} = 123370.055$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = A_s / 2 \cdot A_{stirrup} = 78956.835$   
 $f_y = 420.00$   
 $s = 250.00$   
 $V_{s2}$  is multiplied by  $Col2 = 0.00$   
 $s/d = 1.04167$   
 $V_f$  ((11-3)-(11.4), ACI 440) =  $247653.332$   
 $f = 0.95$ , 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:  $\theta = 45^\circ$   
 $V_f = \min(|V_f(45, \theta)|, |V_f(-45, \theta)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{Dir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) =  $470.00$   
 $f_{fe}$  ((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:  $V_s + V_f \leq 359638.026$   
 $b_w \cdot d = V_u \cdot d / 4 = 125663.706$

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

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

From analysis, chord rotation  $\theta = 0.00016502$   
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.0189444$  ((4.29), Biskinis Phd))  
 $M_y = 4.4260E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) =  $3000.779$   
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 2.3369E+013$   
 $factor = 0.30$   
 $A_g = 196349.541$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.84$

$$N = 7387.347$$

$$Ec \cdot I_g = Ec_{jacket} \cdot I_{g\_jacket} + Ec_{core} \cdot I_{g\_core} = 7.7898E+013$$

Calculation of Yielding Moment  $M_y$

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

$$M_y = \min(M_{y\_ten}, M_{y\_com}) = 4.4260E+008$$

$$\rho_y ((10a) \text{ or } (10b)) = 1.3430729E-005$$

$$M_{y\_ten} (8a) = 4.4260E+008$$

$$\rho_{y\_ten} (7a) = 65.19069$$

$$\text{error of function (7a)} = 0.00234593$$

$$M_{y\_com} (8b) = 7.6083E+008$$

$$\rho_{y\_com} (7b) = 64.49917$$

$$\text{error of function (7b)} = -0.0073398$$

$$\text{with } e_y = 0.003125$$

$$e_{co} = 0.002$$

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

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.0011297$$

$$N = 7387.347$$

$$A_c = 196349.541$$

$$= 0.29185858$$

$$\text{with } f_c^* ((12.3), \text{ACI 440}) = 33.3038$$

$$f_c = 30.00$$

$$f_l = 1.05384$$

$$k = 1$$

$$\text{Effective FRP thickness, } t_f = NL \cdot t \cdot \cos(\theta_1) = 1.016$$

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

$$E_f = 64828.00$$

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 JCC1 of floor 1

At local axis: 2

Integration Section: (a)

## Calculation No. 10

column C1, Floor 1

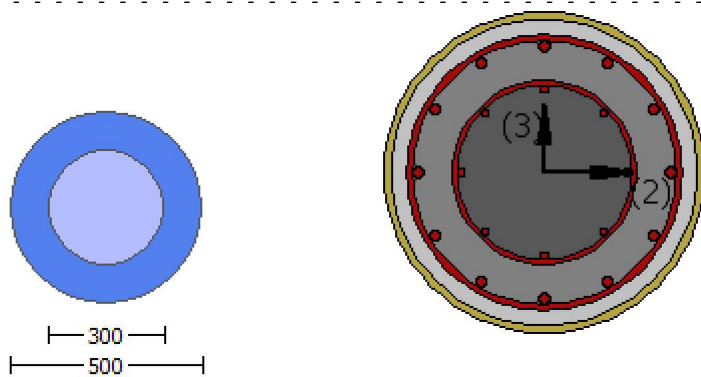
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\phi_r$ )

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 781.25$

Existing Column

Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.50688

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,  $efu = 0.01$

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,  $V_a = 4.1010657E-031$

EDGE -B-

Shear Force,  $V_b = -4.1010657E-031$

BOTH EDGES

Axial Force,  $F = -7389.214$

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,  $V_e/V_r = 0.45961884$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$   
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 4.4703E+008$

$\mu_{1+} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{1-} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 4.4703E+008$

$\mu_{2+} = 4.4703E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 4.4703E+008$ , 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),  $\mu_u$

$\mu_u = 4.4703E+008$

$= 0.97738438$

$' = 0.86668818$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY:  $f_{cc} = f_c^* \quad c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 781.25$

$l_b/l_d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

$= \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.36292832$

Calculation of ratio  $l_b/l_d$

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

Calculation of  $\mu_{1-}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TBDY: fcc = fc\* c = 45.20626  
conf. factor c = 1.50688  
fc = 30.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25  
lb/d = 1.00  
d1 = 44.00  
R = 250.00  
v = 0.00112412  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.36292832

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 = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TBDY: fcc = fc\* c = 45.20626  
conf. factor c = 1.50688  
fc = 30.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25  
lb/d = 1.00  
d1 = 44.00  
R = 250.00  
v = 0.00112412  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.36292832

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 = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TBDY: fcc = fc\* c = 45.20626

conf. factor  $c = 1.50688$   
 $f_c = 30.00$   
 From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 250.00$   
 $v = 0.00112412$   
 $N = 7389.214$   
 $A_c = 196349.541$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$

Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 648405.308$

Calculation of Shear Strength at edge 1,  $V_{r1} = 648405.308$

$V_{r1} = V_{Co1}$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{Co1}$

$V_{Co1} = 648405.308$

$k_{nl} = 1$  (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)

Mean concrete strength:  $f'_c = (f'_c_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f'_c_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f_c^{0.5} \leq 8.3$  MPa ((22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.1425332E-011$

$\nu_u = 4.1010657E-031$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From ((11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$f_y = 625.00$

$s = 100.00$

$V_{s1}$  is multiplied by  $\text{Col1} = 1.00$

$s/d = 0.25$

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

$A_v = \cdot /2 \cdot A_{\text{stirrup}} = 78956.835$

$f_y = 525.00$

$s = 250.00$

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

$s/d = 1.04167$

$V_f$  ((11-3)-(11.4), ACI 440) = 247653.332

$f = 0.95$ , 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 is the angle of the crack direction (see KANEPE).

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

orientation 1:  $\theta_1 = b_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 470.00

$f_{fe}$  ((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:  $V_s + V_f \leq 440464.828$

$$b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 125663.706$$

Calculation of Shear Strength at edge 2,  $V_{r2} = 648405.308$

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

$$V_{Col0} = 648405.308$$

$k_{nl} = 1$  (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)

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.84$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M / Vd = 2.00$$

$$\mu_u = 2.1425332E-011$$

$$V_u = 4.1010657E-031$$

$$d = 0.8 \cdot D = 400.00$$

$$N_u = 7389.214$$

$$A_g = 196349.541$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$$f_y = 625.00$$

$$s = 100.00$$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$$s/d = 0.25$$

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

$$A_v = \frac{1}{2} \cdot A_{stirrup} = 78956.835$$

$$f_y = 525.00$$

$$s = 250.00$$

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

$$s/d = 1.04167$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 247653.332$$

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

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

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 470.00$$

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

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

From (11-11), ACI 440:  $V_s + V_f \leq 440464.828$

$$b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 125663.706$$

End Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjcs

Constant Properties

Knowledge Factor,  $\phi = 1.00$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 781.25$

Existing Column

Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.50688

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,  $ef_u = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $bi: 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

-----

Stepwise Properties

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At local axis: 2

EDGE -A-

Shear Force,  $V_a = -2.5110955E-047$

EDGE -B-

Shear Force,  $V_b = 2.5110955E-047$

BOTH EDGES

Axial Force,  $F = -7389.214$

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:  $As_{l,mid} = 1017.876$

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Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.45961884$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$

with



$$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 4.4703\text{E}+008$$

$M_{u1+} = 4.4703\text{E}+008$ , 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

$M_{u1-} = 4.4703\text{E}+008$ , 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

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 4.4703\text{E}+008$$

$M_{u2+} = 4.4703\text{E}+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 4.4703\text{E}+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $M_{u1+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $M_u$   
 $M_u = 4.4703\text{E}+008$

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TDY:  $f_{cc} = f_c \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$$f_c = 30.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

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),  $M_u$   
 $M_u = 4.4703\text{E}+008$

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TDY:  $f_{cc} = f_c \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$$f_c = 30.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

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 = 4.4703E+008

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: fcc = fc\* c = 45.20626

conf. factor c = 1.50688

fc = 30.00

From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25

$$lb/d = 1.00$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1,1.25*(lb/d)^ 2/3) = 0.36292832$$

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 = 4.4703E+008

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: fcc = fc\* c = 45.20626

conf. factor c = 1.50688

fc = 30.00

From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25

$$lb/d = 1.00$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1,1.25*(lb/d)^ 2/3) = 0.36292832$$

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 648405.308

Calculation of Shear Strength at edge 1, Vr1 = 648405.308

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

$$VColO = 648405.308$$

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)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$f_y = 625.00$

$s = 100.00$

$V_{s1}$  is multiplied by  $\text{Col1} = 1.00$

$s/d = 0.25$

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

$A_v = \frac{1}{2} \cdot A_{\text{stirrup}} = 78956.835$

$f_y = 525.00$

$s = 250.00$

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

$s/d = 1.04167$

$V_f$  ((11-3)-(11.4), ACI 440) = 247653.332

$f = 0.95$ , 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) = 470.00

$f_{fe}$  ((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:  $V_s + V_f \leq 440464.828$

$b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 648405.308$

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

$V_{\text{Col0}} = 648405.308$

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)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$f_y = 625.00$

$s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s2}$  is multiplied by  $Col2 = 0.00$   
 $s/d = 1.04167$   
 $V_f ((11-3)-(11.4), ACI 440) = 247653.332$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 470.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 440464.828$   
 $b_w \cdot d = \sqrt{V_s + V_f} \cdot d / 4 = 125663.706$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1  
 At local axis: 2  
 -----

Start Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1  
 At local axis: 2  
 Integration Section: (a)  
 Section Type: rcjcs

Constant Properties

-----  
 Knowledge Factor,  $\phi = 1.00$   
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.  
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
 Concrete Elasticity,  $E_c = 25742.96$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 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,  $E_s = 200000.00$   
 External Diameter,  $D = 500.00$   
 Internal Diameter,  $D = 300.00$   
 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,  $N_{oDir} = 1$

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = 6.3791133E-010$

Shear Force,  $V_2 = -4667.709$

Shear Force,  $V_3 = -1.6819047E-013$

Axial Force,  $F = -7387.347$

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  $u_R = u = 0.05990359$

$u = y + p = 0.05990359$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00946974$  ((4.29), Biskinis Phd))

$M_y = 4.4260E+008$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.3369E+013$

factor = 0.30

$A_g = 196349.541$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.84$

$N = 7387.347$

$E_c * I_g = E_c * I_{g,jacket} + E_c * I_{g,core} = 7.7898E+013$

#### Calculation of Yielding Moment $M_y$

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

$M_y = \min(M_{y,ten}, M_{y,com}) = 4.4260E+008$

$y$  ((10a) or (10b)) = 1.3430729E-005

$M_{y,ten}$  (8a) = 4.4260E+008

$y_{ten}$  (7a) = 65.19069

error of function (7a) = 0.00234593

$M_{y,com}$  (8b) = 7.6083E+008

$y_{com}$  (7b) = 64.49917

error of function (7b) = -0.0073398

with  $e_y = 0.003125$

$e_{co} = 0.002$

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

$d_1 = 44.00$

$R = 250.00$

$v = 0.0011297$

$N = 7387.347$

$A_c = 196349.541$

$= 0.29185858$   
 with  $f_c^*$  ((12.3), ACI 440) = 33.3038  
 $f_c = 30.00$   
 $f_l = 1.05384$   
 $k = 1$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $e_{fe}$  ((12.5) and (12.7)) = 0.004  
 $E_f = 64828.00$

Calculation of ratio  $l_b/l_d$

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

- Calculation of  $p$  -

From table 10-9:  $p = 0.05043385$

with:

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

shear control ratio  $V_y E / V_{col} O E = 0.45961884$

$d = d_{external} = 0.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00660658$

jacket:  $s_1 = A_{v1} \cdot (D_{c1} / 2) / (s_1 \cdot A_g) = 0.0027646$

$A_{v1} = 78.53982$ , is the area of stirrup

$D_{c1} = D_{ext} - 2 \cdot cover - \text{External Hoop Diameter} = 440.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2} \cdot (D_{c2} / 2) / (s_2 \cdot A_g) = 0.00046968$

$A_{v2} = 50.26548$ , is the area of stirrup

$D_{c2} = D_{int} - \text{Internal Hoop Diameter} = 292.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

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.

For the normalisation  $f_s$  of jacket is used.

$N_{UD} = 7387.347$

$A_g = 196349.541$

$f_{cE} = (f_{c,jacket} \cdot \text{Area}_{jacket} + f_{c,core} \cdot \text{Area}_{core}) / \text{section\_area} = 27.84$

$f_{yLE} = (f_{y,ext\_Long\_Reinf} \cdot \text{Area}_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} \cdot \text{Area}_{int\_Long\_Reinf}) / \text{Area}_{Tot\_Long\_Rein} = 21219958E-314$

$f_{yTE} = (f_{y,ext\_Trans\_Reinf} \cdot \text{Area}_{ext\_Trans\_Reinf} + f_{y,int\_Trans\_Reinf} \cdot \text{Area}_{int\_Trans\_Reinf}) / \text{Area}_{Tot\_Trans\_Rein} = 610.4781$

$p_l = \text{Area}_{Tot\_Long\_Rein} / (A_g) = 0.015552$

$f_{cE} = 27.84$

End Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1

At local axis: 2

Integration Section: (a)

**Calculation No. 11**

column C1, Floor 1

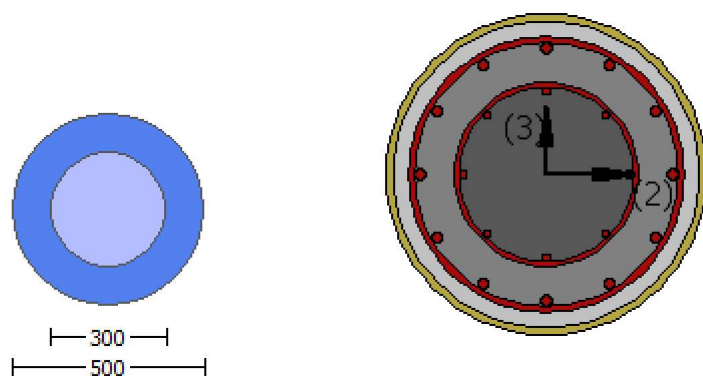
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JCC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 20.00$

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

Jacket

New material: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material: Steel Strength,  $f_s = f_{sm} = 625.00$

Existing Column

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

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

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

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,  $N_{oDir} = 1$   
 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,  $M_a = 6.3791133E-010$   
 Shear Force,  $V_a = -1.6819047E-013$   
 EDGE -B-  
 Bending Moment,  $M_b = -1.3314306E-010$   
 Shear Force,  $V_b = 1.6819047E-013$   
 BOTH EDGES  
 Axial Force,  $F = -7387.347$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{sl,t} = 0.00$   
   -Compression:  $A_{sl,c} = 3053.628$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{sl,ten} = 1017.876$   
   -Compression:  $A_{sl,com} = 1017.876$   
   -Middle:  $A_{sl,mid} = 1017.876$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = V_n = 529689.402$   
 $V_n ((10.3), ASCE 41-17) = k_n l^* V_{CoI0} = 529689.402$   
 $V_{CoI} = 529689.402$   
 $k_n l = 1.00$   
 $displacement\_ductility\_demand = 0.00$

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)  
 Mean concrete strength:  $f'_c = (f'_c\_jacket * Area\_jacket + f'_c\_core * Area\_core) / Area\_section = 18.56$ , but  $f'_c^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $M_u = 6.3791133E-010$   
 $V_u = 1.6819047E-013$   
 $d = 0.8 * D = 400.00$   
 $N_u = 7387.347$   
 $A_g = 196349.541$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 246740.11$   
 $V_{s1} = 246740.11$  is calculated for jacket, with:  
 $A_v = A_{stirrup} / 2 = 123370.055$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = A_{stirrup} / 2 = 78956.835$   
 $f_y = 420.00$   
 $s = 250.00$



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

$s/d = 1.04167$

$V_f((11-3)-(11.4), ACI\ 440) = 247653.332$

$f = 0.95$ , 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:  $\theta = b1 + 90^\circ = 90.00$

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

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

$dfv = d$  (figure 11.2, ACI 440) = 470.00

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 359638.026$

$bw \cdot d = \rho \cdot d^2 / 4 = 125663.706$

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  $\theta = 8.9164805E-021$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00946974$  ((4.29), Biskinis Phd))

$M_y = 4.4260E+008$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 2.3369E+013$

factor = 0.30

$A_g = 196349.541$

Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot Area\_jacket + f'_{c\_core} \cdot Area\_core) / Area\_section = 27.84$

$N = 7387.347$

$E_c \cdot I_g = E_{c\_jacket} \cdot I_{g\_jacket} + E_{c\_core} \cdot I_{g\_core} = 7.7898E+013$

Calculation of Yielding Moment  $M_y$

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

$M_y = \text{Min}(M_{y\_ten}, M_{y\_com}) = 4.4260E+008$

$y$  ((10a) or (10b)) = 1.3430729E-005

$M_{y\_ten}$  (8a) = 4.4260E+008

$\delta_{ten}$  (7a) = 65.19069

error of function (7a) = 0.00234593

$M_{y\_com}$  (8b) = 7.6083E+008

$\delta_{com}$  (7b) = 64.49917

error of function (7b) = -0.0073398

with  $e_y = 0.003125$

$e_{co} = 0.002$

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

$d1 = 44.00$

$R = 250.00$

$v = 0.0011297$

$N = 7387.347$

$A_c = 196349.541$

$\rho = 0.29185858$

with  $f'_c$  ((12.3), ACI 440) = 33.3038

$f_c = 30.00$

$fl = 1.05384$

$k = 1$

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

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

Ef = 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 JCC1 of floor 1

At local axis: 3

Integration Section: (a)

## Calculation No. 12

column C1, Floor 1

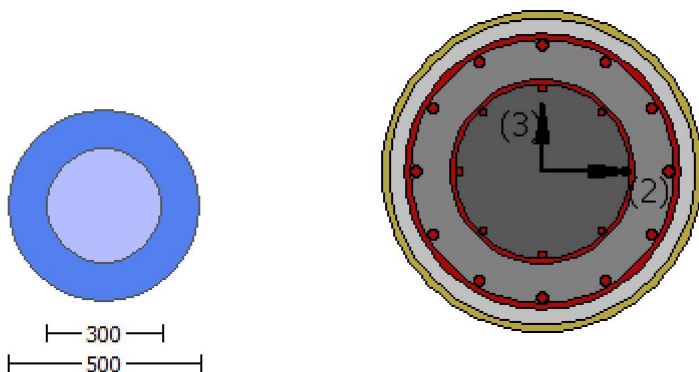
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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  
Jacket  
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 781.25$   
Existing Column  
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
#####  
External Diameter,  $D = 500.00$   
Internal Diameter,  $D = 300.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.50688  
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,  $V_a = 4.1010657E-031$   
EDGE -B-  
Shear Force,  $V_b = -4.1010657E-031$   
BOTH EDGES  
Axial Force,  $F = -7389.214$   
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,  $V_e/V_r = 0.45961884$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$   
with  
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 4.4703E+008$   
 $\mu_{u1+} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction  
which is defined for the static loading combination  
 $\mu_{u1-} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment  
direction which is defined for the static loading combination  
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 4.4703E+008$   
 $\mu_{u2+} = 4.4703E+008$ , 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

Mu2- = 4.4703E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu1+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TDY: fcc = fc\* c = 45.20626  
conf. factor c = 1.50688  
fc = 30.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25  
lb/d = 1.00  
d1 = 44.00  
R = 250.00  
v = 0.00112412  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.36292832

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 = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TDY: fcc = fc\* c = 45.20626  
conf. factor c = 1.50688  
fc = 30.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25  
lb/d = 1.00  
d1 = 44.00  
R = 250.00  
v = 0.00112412  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.36292832

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

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

$$\mu_u = 4.4703E+008$$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TB DY:  $f_{cc} = f_c \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_u$ -

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

$$\mu_u = 4.4703E+008$$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TB DY:  $f_{cc} = f_c \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 648405.308$

Calculation of Shear Strength at edge 1,  $V_{r1} = 648405.308$

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

$V_{c0} = 648405.308$

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

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

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

$= 1$  (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_c \cdot \text{jacket} \cdot \text{Area}_{\text{jacket}} + f'_c \cdot \text{core} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$   
 $\mu_u = 2.1425332E-011$   
 $\mu_v = 4.1010657E-031$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7389.214$   
 $A_g = 196349.541$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$   
 $V_{s1} = 308425.138$  is calculated for jacket, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $\text{Col1} = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s2}$  is multiplied by  $\text{Col2} = 0.00$   
 $s/d = 1.04167$   
 $V_f ((11-3)-(11.4), \text{ACI 440}) = 247653.332$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 470.00  
 $f_{fe} ((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 440464.828$   
 $b_w \cdot d = \sqrt{4} \cdot d \cdot d / 4 = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 648405.308$   
 $V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE 41-17}) = k_n l \cdot V_{\text{Col0}}$   
 $V_{\text{Col0}} = 648405.308$   
 $k_n l = 1$  (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).

$\gamma_c = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_c \cdot \text{Area}_{\text{jacket}} + f'_c \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f'_c^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 2.1425332E-011$   
 $\mu_v = 4.1010657E-031$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7389.214$   
 $A_g = 196349.541$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$   
 $V_{s1} = 308425.138$  is calculated for jacket, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $\text{Col1} = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s2}$  is multiplied by  $\text{Col2} = 0.00$

$s/d = 1.04167$   
 $V_f((11-3)-(11.4), \text{ACI 440}) = 247653.332$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = NL \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 470.00  
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 440464.828$   
 $b_w \cdot d = \frac{V_s \cdot d}{4} = 125663.706$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1  
 At local axis: 3  
 -----

-----  
 Start Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1  
 At Shear local axis: 2  
 (Bending local axis: 3)  
 Section Type: rcjcs

#### Constant Properties

-----  
 Knowledge Factor,  $\gamma = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
 Concrete Elasticity,  $E_c = 25742.96$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 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  
 Jacket  
 New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 781.25$   
 Existing Column  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
 #####  
 External Diameter,  $D = 500.00$   
 Internal Diameter,  $D = 300.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.50688  
 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 ( $l_o/l_{o,u,min} \geq 1$ )  
 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,  $V_a = -2.5110955E-047$

EDGE -B-

Shear Force,  $V_b = 2.5110955E-047$

BOTH EDGES

Axial Force,  $F = -7389.214$

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,  $V_e/V_r = 0.45961884$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$   
with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 4.4703E+008$

$Mu_{1+} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 4.4703E+008$

$Mu_{2+} = 4.4703E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 4.4703E+008$ , 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),  $M_u$

$M_u = 4.4703E+008$

$\phi = 0.97738438$

$\phi' = 0.86668818$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY:  $f_{cc} = f_c^* \quad c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y * \text{Min}(1, 1.25 * (l_b/d)^{2/3}) = 781.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$



$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

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),  $\mu$   
 $\mu = 4.4703\text{E}+008$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TDY:  $f_{cc} = f_c \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

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),  $\mu$   
 $\mu = 4.4703\text{E}+008$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TDY:  $f_{cc} = f_c \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

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 = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TBDY:  $f_{cc} = f_c' \cdot c = 45.20626$   
conf. factor  $c = 1.50688$   
 $f_c = 30.00$   
From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 250.00$   
 $v = 0.00112412$   
 $N = 7389.214$   
 $A_c = 196349.541$   
=  $\cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$

## Calculation of ratio $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 648405.308$

Calculation of Shear Strength at edge 1,  $V_{r1} = 648405.308$

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

$V_{Co10} = 648405.308$

$k_{nl} = 1$  (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)  
Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f_c'^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 2.0093280E-011$   
 $\mu_v = 2.5110955E-047$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7389.214$   
 $A_g = 196349.541$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$   
 $V_{s1} = 308425.138$  is calculated for jacket, with:  
 $A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 123370.055$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $\text{Col1} = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 78956.835$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s2}$  is multiplied by  $\text{Col2} = 0.00$   
 $s/d = 1.04167$   
 $V_f ((11-3)-(11.4), ACI 440) = 247653.332$   
 $f = 0.95$ , 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) = 470.00

$f_{fe}$  ((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:  $V_s + V_f \leq 440464.828$

$b_w \cdot d = \sqrt{d} \cdot d / 4 = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 648405.308$

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

$V_{Col0} = 648405.308$

$k_{nl} = 1$  (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).

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

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$f_y = 625.00$

$s = 100.00$

$V_{s1}$  is multiplied by  $\text{Col1} = 1.00$

$s/d = 0.25$

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

$A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 78956.835$

$f_y = 525.00$

$s = 250.00$

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

$s/d = 1.04167$

$V_f$  ((11-3)-(11.4), ACI 440) = 247653.332

$f = 0.95$ , 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  $(\cot \theta + \csc \theta) \sin \alpha$  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  $\theta_i$ , 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) = 470.00

$f_{fe}$  ((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:  $V_s + V_f \leq 440464.828$

$b_w \cdot d = \sqrt{d} \cdot d / 4 = 125663.706$

End Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjcs

#### Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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,  $E_s = 200000.00$

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

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,  $N_{oDir} = 1$

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -1.4007E+007$

Shear Force,  $V_2 = -4667.709$

Shear Force,  $V_3 = -1.6819047E-013$

Axial Force,  $F = -7387.347$

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:  $As_{l,mid} = 1017.876$

Mean Diameter of Tension Reinforcement,  $Db_L = 18.00$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = * u = 0.06937825$

$u = y + p = 0.06937825$

- Calculation of  $\phi_y$  -

$$\phi_y = (M_y * L_s / 3) / E_{eff} = 0.0189444 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 4.4260E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 3000.779$$

$$\text{From table 10.5, ASCE 41_17: } E_{eff} = \text{factor} * E_c * I_g = 2.3369E+013$$

$$\text{factor} = 0.30$$

$$A_g = 196349.541$$

$$\text{Mean concrete strength: } f'_c = (f'_{c\_jacket} * A_{jacket} + f'_{c\_core} * A_{core}) / A_{section} = 27.84$$

$$N = 7387.347$$

$$E_c * I_g = E_{c\_jacket} * I_{g\_jacket} + E_{c\_core} * I_{g\_core} = 7.7898E+013$$

Calculation of Yielding Moment  $M_y$

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

$$M_y = \text{Min}(M_{y\_ten}, M_{y\_com}) = 4.4260E+008$$

$$\phi_y \text{ ((10a) or (10b))} = 1.3430729E-005$$

$$M_{y\_ten} \text{ (8a)} = 4.4260E+008$$

$$\phi_{y\_ten} \text{ (7a)} = 65.19069$$

$$\text{error of function (7a)} = 0.00234593$$

$$M_{y\_com} \text{ (8b)} = 7.6083E+008$$

$$\phi_{y\_com} \text{ (7b)} = 64.49917$$

$$\text{error of function (7b)} = -0.0073398$$

$$\text{with } e_y = 0.003125$$

$$e_{co} = 0.002$$

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

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.0011297$$

$$N = 7387.347$$

$$A_c = 196349.541$$

$$= 0.29185858$$

$$\text{with } f'_c \text{ ((12.3), ACI 440)} = 33.3038$$

$$f_c = 30.00$$

$$f_l = 1.05384$$

$$k = 1$$

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

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

$$E_f = 64828.00$$

Calculation of ratio  $l_b/d$

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

- Calculation of  $\phi_p$  -

$$\text{From table 10-9: } \phi_p = 0.05043385$$

with:

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

$$\text{shear control ratio } V_y E / V_{co} I_{OE} = 0.45961884$$

$$d = d_{external} = 0.00$$

$$s = s_{external} = 0.00$$

$$t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00660658$$

$$\text{jacket: } s_1 = A_{v1} * (D_{c1} / 2) / (s_1 * A_g) = 0.0027646$$

$$A_{v1} = 78.53982, \text{ is the area of stirrup}$$

$$D_{c1} = D_{ext} - 2 * \text{cover} - \text{External Hoop Diameter} = 440.00, \text{ is the total Length of all stirrups parallel to loading}$$

(shear) direction

$$s_1 = 100.00$$

$$\text{core: } s_2 = A_{v2} * (D_{c2} / 2) / (s_2 * A_g) = 0.00046968$$

$$A_{v2} = 50.26548, \text{ is the area of stirrup}$$

$$D_{c2} = D_{int} - \text{Internal Hoop Diameter} = 292.00, \text{ is the total Length of all stirrups parallel to loading (shear)}$$

direction

$$s2 = 250.00$$

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.

For the normalisation  $f_s$  of jacket is used.

$$N_{UD} = 7387.347$$

$$A_g = 196349.541$$

$$f_{cE} = (f_{c\_jacket} \cdot Area\_jacket + f_{c\_core} \cdot Area\_core) / section\_area = 27.84$$

$$f_{yE} = (f_{y\_ext\_Long\_Reinf} \cdot Area\_ext\_Long\_Reinf + f_{y\_int\_Long\_Reinf} \cdot Area\_int\_Long\_Reinf) / Area\_Tot\_Long\_Rein = 21219958E-314$$

$$f_{yE} = (f_{y\_ext\_Trans\_Reinf} \cdot Area\_ext\_Trans\_Reinf + f_{y\_int\_Trans\_Reinf} \cdot Area\_int\_Trans\_Reinf) / Area\_Tot\_Trans\_Rein = 610.4781$$

$$\rho_l = Area\_Tot\_Long\_Rein / (A_g) = 0.015552$$

$$f_{cE} = 27.84$$

End Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1

At local axis: 3

Integration Section: (a)

## Calculation No. 13

column C1, Floor 1

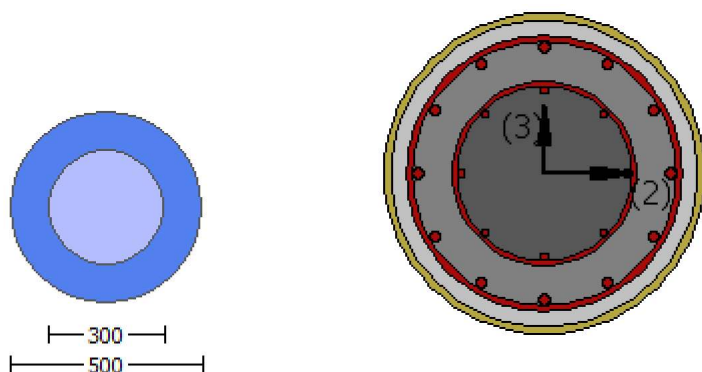
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JCC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rcjcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$   
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.  
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 20.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
Concrete Elasticity,  $E_c = 25742.96$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
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, ASCE 41-17) because bending is considered as  
Deformation-Controlled Action (Table C7-1, ASCE 41-17).  
Jacket  
New material: Concrete Strength,  $f_c = f_{cm} = 30.00$   
New material: Steel Strength,  $f_s = f_{sm} = 625.00$   
Existing Column  
Existing material: Concrete Strength,  $f_c = f_{cm} = 24.00$   
Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$   
#####  
External Diameter,  $D = 500.00$   
Internal Diameter,  $D = 300.00$   
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,  $ef_u = 0.01$   
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,  $M_a = -1.4007E+007$   
Shear Force,  $V_a = -4667.709$   
EDGE -B-  
Bending Moment,  $M_b = 0.10299595$   
Shear Force,  $V_b = 4667.709$   
BOTH EDGES  
Axial Force,  $F = -7387.347$   
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  $V_R = V_n = 529689.402$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n V_{Col0} = 529689.402$   
 $V_{Col} = 529689.402$   
 $k_n = 1.00$   
 $displacement\_ductility\_demand = 0.04746465$

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)  
 Mean concrete strength:  $f'_c = (f'_c\_jacket \cdot Area\_jacket + f'_c\_core \cdot Area\_core) / Area\_section = 18.56$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 0.10299595$   
 $V_u = 4667.709$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7387.347$   
 $A_g = 196349.541$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 246740.11$   
 $V_{s1} = 246740.11$  is calculated for jacket, with:  
 $A_v = A_s / 2 = 123370.055$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = A_s / 2 = 78956.835$   
 $f_y = 420.00$   
 $s = 250.00$   
 $V_{s2}$  is multiplied by  $Col2 = 0.00$   
 $s/d = 1.04167$   
 $V_f$  ((11-3)-(11.4), ACI 440) =  $247653.332$   
 $f = 0.95$ , 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  $V_f(a)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a = b1 + 90^\circ = 90.00$   
 $V_f = \min(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{Dir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) =  $470.00$   
 $f_{fe}$  ((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:  $V_s + V_f \leq 359638.026$   
 $b_w \cdot d = V_u \cdot d / 4 = 125663.706$

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

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

From analysis, chord rotation  $\theta = 8.9895615E-005$   
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00189395$  ((4.29), Biskinis Phd))  
 $M_y = 4.4260E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) =  $300.00$   
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 2.3369E+013$   
 $factor = 0.30$   
 $A_g = 196349.541$   
 Mean concrete strength:  $f'_c = (f'_c\_jacket \cdot Area\_jacket + f'_c\_core \cdot Area\_core) / Area\_section = 27.84$



$$N = 7387.347$$

$$Ec \cdot I_g = Ec_{jacket} \cdot I_{g\_jacket} + Ec_{core} \cdot I_{g\_core} = 7.7898E+013$$

Calculation of Yielding Moment  $M_y$

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

$$M_y = \min(M_{y\_ten}, M_{y\_com}) = 4.4260E+008$$

$$\rho_y ((10a) \text{ or } (10b)) = 1.3430729E-005$$

$$M_{y\_ten} (8a) = 4.4260E+008$$

$$\rho_{y\_ten} (7a) = 65.19069$$

$$\text{error of function (7a)} = 0.00234593$$

$$M_{y\_com} (8b) = 7.6083E+008$$

$$\rho_{y\_com} (7b) = 64.49917$$

$$\text{error of function (7b)} = -0.0073398$$

$$\text{with } e_y = 0.003125$$

$$e_{co} = 0.002$$

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

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.0011297$$

$$N = 7387.347$$

$$A_c = 196349.541$$

$$= 0.29185858$$

$$\text{with } f_c^* ((12.3), \text{ACI 440}) = 33.3038$$

$$f_c = 30.00$$

$$f_l = 1.05384$$

$$k = 1$$

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

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

$$E_f = 64828.00$$

Calculation of ratio  $I_b/I_d$

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

End Of Calculation of Shear Capacity for element: column JCC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 14

column C1, Floor 1

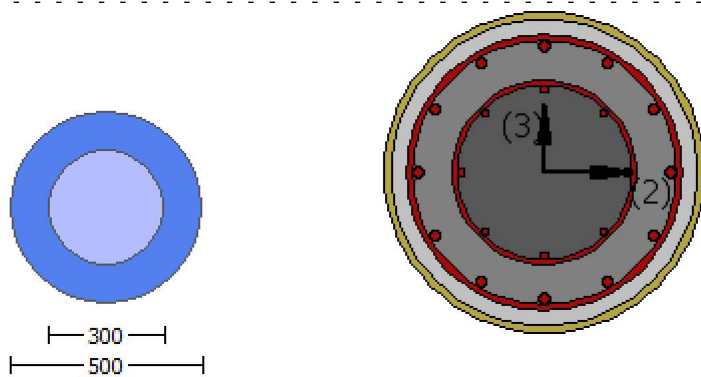
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\phi_r$ )

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 781.25$

Existing Column

Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.50688

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,  $efu = 0.01$

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,  $V_a = 4.1010657E-031$

EDGE -B-

Shear Force,  $V_b = -4.1010657E-031$

BOTH EDGES

Axial Force,  $F = -7389.214$

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,  $V_e/V_r = 0.45961884$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$   
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 4.4703E+008$

$\mu_{1+} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{1-} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 4.4703E+008$

$\mu_{2+} = 4.4703E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 4.4703E+008$ , 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),  $\mu_u$

$\mu_u = 4.4703E+008$

$\phi = 0.97738438$

$\phi' = 0.86668818$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TDY:  $f_{cc} = f_c^* \quad c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 781.25$

$l_b/l_d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

$= \phi \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.36292832$

Calculation of ratio  $l_b/l_d$

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

Calculation of  $\mu_{1-}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TDY: fcc = fc\* c = 45.20626  
conf. factor c = 1.50688  
fc = 30.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25  
lb/d = 1.00  
d1 = 44.00  
R = 250.00  
v = 0.00112412  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.36292832

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 = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TDY: fcc = fc\* c = 45.20626  
conf. factor c = 1.50688  
fc = 30.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25  
lb/d = 1.00  
d1 = 44.00  
R = 250.00  
v = 0.00112412  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.36292832

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 = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TDY: fcc = fc\* c = 45.20626

conf. factor  $c = 1.50688$   
 $f_c = 30.00$   
 From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$   
 $l_b/d = 1.00$   
 $d_1 = 44.00$   
 $R = 250.00$   
 $v = 0.00112412$   
 $N = 7389.214$   
 $A_c = 196349.541$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$

Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 648405.308$

Calculation of Shear Strength at edge 1,  $V_{r1} = 648405.308$

$V_{r1} = V_{Co1}$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{Co1}$

$V_{Co1} = 648405.308$

$k_{nl} = 1$  (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)

Mean concrete strength:  $f'_c = (f'_c_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f'_c_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f_c^{0.5} \leq 8.3$  MPa ((22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.1425332E-011$

$\nu_u = 4.1010657E-031$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From ((11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$f_y = 625.00$

$s = 100.00$

$V_{s1}$  is multiplied by  $\text{Col1} = 1.00$

$s/d = 0.25$

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

$A_v = \cdot /2 \cdot A_{\text{stirrup}} = 78956.835$

$f_y = 525.00$

$s = 250.00$

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

$s/d = 1.04167$

$V_f$  ((11-3)-(11.4), ACI 440) = 247653.332

$f = 0.95$ , 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  $\alpha$  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,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 470.00

$f_{fe}$  ((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:  $V_s + V_f \leq 440464.828$

$$b_w \cdot d = \frac{1}{4} \cdot d^2 = 125663.706$$

Calculation of Shear Strength at edge 2,  $V_{r2} = 648405.308$

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

$$V_{Col0} = 648405.308$$

$k_{nl} = 1$  (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)

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.84$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M / Vd = 2.00$$

$$\mu_u = 2.1425332E-011$$

$$\nu_u = 4.1010657E-031$$

$$d = 0.8 \cdot D = 400.00$$

$$N_u = 7389.214$$

$$A_g = 196349.541$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$$f_y = 625.00$$

$$s = 100.00$$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$$s/d = 0.25$$

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

$$A_v = \frac{1}{2} \cdot A_{stirrup} = 78956.835$$

$$f_y = 525.00$$

$$s = 250.00$$

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

$$s/d = 1.04167$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 247653.332$$

$f = 0.95$ , for fully-wrapped sections

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

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot_a) \sin \alpha$  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:  $\alpha = b1 + 90^\circ = 90.00$

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

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

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 470.00$$

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

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

From (11-11), ACI 440:  $V_s + V_f \leq 440464.828$

$$b_w \cdot d = \frac{1}{4} \cdot d^2 = 125663.706$$

End Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjcs

Constant Properties

Knowledge Factor,  $= 1.00$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 781.25$

Existing Column

Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.50688

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,  $ef_u = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $bi: 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

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Stepwise Properties

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At local axis: 2

EDGE -A-

Shear Force,  $V_a = -2.5110955E-047$

EDGE -B-

Shear Force,  $V_b = 2.5110955E-047$

BOTH EDGES

Axial Force,  $F = -7389.214$

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:  $As_{l,mid} = 1017.876$

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Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.45961884$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$

with

$$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 4.4703\text{E}+008$$

$M_{u1+} = 4.4703\text{E}+008$ , 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

$M_{u1-} = 4.4703\text{E}+008$ , 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

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 4.4703\text{E}+008$$

$M_{u2+} = 4.4703\text{E}+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 4.4703\text{E}+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $M_{u1+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $M_u$   
 $M_u = 4.4703\text{E}+008$

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TDY:  $f_{cc} = f_c \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$$f_c = 30.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

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),  $M_u$   
 $M_u = 4.4703\text{E}+008$

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TDY:  $f_{cc} = f_c \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$$f_c = 30.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

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 = 4.4703E+008

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: fcc = fc\* c = 45.20626

conf. factor c = 1.50688

fc = 30.00

From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25

$$lb/d = 1.00$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1,1.25*(lb/d)^ 2/3) = 0.36292832$$

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 = 4.4703E+008

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: fcc = fc\* c = 45.20626

conf. factor c = 1.50688

fc = 30.00

From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25

$$lb/d = 1.00$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1,1.25*(lb/d)^ 2/3) = 0.36292832$$

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 648405.308

Calculation of Shear Strength at edge 1, Vr1 = 648405.308

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

$$VColO = 648405.308$$

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)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$f_y = 625.00$

$s = 100.00$

$V_{s1}$  is multiplied by  $\text{Col1} = 1.00$

$s/d = 0.25$

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

$A_v = \pi/2 \cdot A_{\text{stirrup}} = 78956.835$

$f_y = 525.00$

$s = 250.00$

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

$s/d = 1.04167$

$V_f$  ((11-3)-(11.4), ACI 440) = 247653.332

$f = 0.95$ , 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:  $\theta_1 = b_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 470.00

$f_{fe}$  ((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:  $V_s + V_f \leq 440464.828$

$b_w \cdot d = \pi \cdot d^2 / 4 = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 648405.308$

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

$V_{\text{Col0}} = 648405.308$

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)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$f_y = 625.00$

$s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s2}$  is multiplied by  $Col2 = 0.00$   
 $s/d = 1.04167$   
 $V_f ((11-3)-(11.4), ACI 440) = 247653.332$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 470.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 440464.828$   
 $b_w \cdot d = \sqrt{V_s + V_f} \cdot d / 4 = 125663.706$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1  
 At local axis: 2  
 -----

Start Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1  
 At local axis: 2  
 Integration Section: (b)  
 Section Type: rcjcs

Constant Properties

-----  
 Knowledge Factor,  $\phi = 1.00$   
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.  
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
 Concrete Elasticity,  $E_c = 25742.96$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 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,  $E_s = 200000.00$   
 External Diameter,  $D = 500.00$   
 Internal Diameter,  $D = 300.00$   
 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,  $N_{oDir} = 1$

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -1.3314306E-010$

Shear Force,  $V_2 = 4667.709$

Shear Force,  $V_3 = 1.6819047E-013$

Axial Force,  $F = -7387.347$

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  $u_R = u = 0.05990359$

$u = y + p = 0.05990359$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00946974$  ((4.29), Biskinis Phd))

$M_y = 4.4260E+008$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} * E_c * I_g = 2.3369E+013$

factor = 0.30

$A_g = 196349.541$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} * A_{\text{jacket}} + f_c'_{\text{core}} * A_{\text{core}}) / A_{\text{section}} = 27.84$

$N = 7387.347$

$E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 7.7898E+013$

#### Calculation of Yielding Moment $M_y$

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

$M_y = \text{Min}(M_{y,ten}, M_{y,com}) = 4.4260E+008$

$y$  ((10a) or (10b)) = 1.3430729E-005

$M_{y,ten}$  (8a) = 4.4260E+008

$y_{ten}$  (7a) = 65.19069

error of function (7a) = 0.00234593

$M_{y,com}$  (8b) = 7.6083E+008

$y_{com}$  (7b) = 64.49917

error of function (7b) = -0.0073398

with  $e_y = 0.003125$

$e_{co} = 0.002$

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

$d_1 = 44.00$

$R = 250.00$

$v = 0.0011297$

$N = 7387.347$

$A_c = 196349.541$

$= 0.29185858$   
 with  $f_c^*$  ((12.3), ACI 440) = 33.3038  
 $f_c = 30.00$   
 $f_l = 1.05384$   
 $k = 1$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $e_{fe}$  ((12.5) and (12.7)) = 0.004  
 $E_f = 64828.00$

Calculation of ratio  $l_b/l_d$

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

- Calculation of  $p$  -

From table 10-9:  $p = 0.05043385$

with:

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

shear control ratio  $V_y E / V_{col} O E = 0.45961884$

$d = d_{external} = 0.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00660658$

jacket:  $s_1 = A_{v1} \cdot (D_{c1} / 2) / (s_1 \cdot A_g) = 0.0027646$

$A_{v1} = 78.53982$ , is the area of stirrup

$D_{c1} = D_{ext} - 2 \cdot \text{cover} - \text{External Hoop Diameter} = 440.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2} \cdot (D_{c2} / 2) / (s_2 \cdot A_g) = 0.00046968$

$A_{v2} = 50.26548$ , is the area of stirrup

$D_{c2} = D_{int} - \text{Internal Hoop Diameter} = 292.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

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.

For the normalisation  $f_s$  of jacket is used.

$N_{UD} = 7387.347$

$A_g = 196349.541$

$f_{cE} = (f_{c,jacket} \cdot \text{Area}_{jacket} + f_{c,core} \cdot \text{Area}_{core}) / \text{section\_area} = 27.84$

$f_{yLE} = (f_{y,ext\_Long\_Reinf} \cdot \text{Area}_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} \cdot \text{Area}_{int\_Long\_Reinf}) / \text{Area\_Tot\_Long\_Rein} = 21219958E-314$

$f_{yTE} = (f_{y,ext\_Trans\_Reinf} \cdot \text{Area}_{ext\_Trans\_Reinf} + f_{y,int\_Trans\_Reinf} \cdot \text{Area}_{int\_Trans\_Reinf}) / \text{Area\_Tot\_Trans\_Rein} = 610.4781$

$p_l = \text{Area\_Tot\_Long\_Rein} / (A_g) = 0.015552$

$f_{cE} = 27.84$

End Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 15

column C1, Floor 1

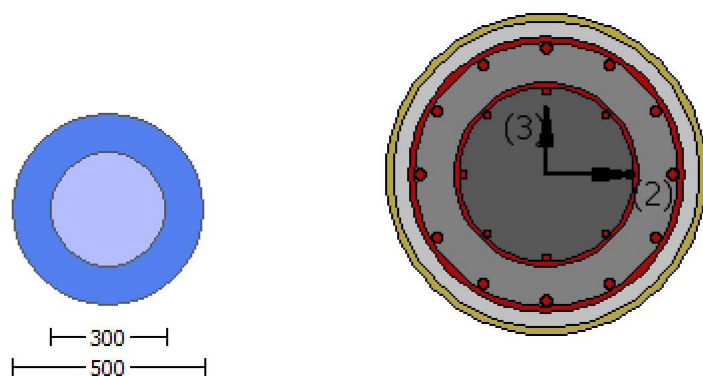
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JCC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcjcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 20.00$

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

Jacket

New material: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material: Steel Strength,  $f_s = f_{sm} = 625.00$

Existing Column

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

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

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

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,  $ε_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i: 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

EDGE -A-  
 Bending Moment,  $M_a = 6.3791133E-010$   
 Shear Force,  $V_a = -1.6819047E-013$   
 EDGE -B-  
 Bending Moment,  $M_b = -1.3314306E-010$   
 Shear Force,  $V_b = 1.6819047E-013$   
 BOTH EDGES  
 Axial Force,  $F = -7387.347$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{sl,t} = 0.00$   
   -Compression:  $A_{sl,c} = 3053.628$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{sl,ten} = 1017.876$   
   -Compression:  $A_{sl,com} = 1017.876$   
   -Middle:  $A_{sl,mid} = 1017.876$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = V_n = 529689.402$   
 $V_n ((10.3), ASCE 41-17) = k_n \cdot V_{CoI0} = 529689.402$   
 $V_{CoI} = 529689.402$   
 $k_n = 1.00$   
 $displacement\_ductility\_demand = 0.00$

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

$\phi = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 18.56$ , but  $f'_c^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.3314306E-010$   
 $\nu_u = 1.6819047E-013$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7387.347$   
 $A_g = 196349.541$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 246740.11$   
 $V_{s1} = 246740.11$  is calculated for jacket, with:  
 $A_v = A_{stirrup} / 2 = 123370.055$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $\phi_{Col1} = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = A_{stirrup} / 2 = 78956.835$   
 $f_y = 420.00$   
 $s = 250.00$

$V_{s2}$  is multiplied by  $Col2 = 0.00$   
 $s/d = 1.04167$   
 $V_f((11-3)-(11.4), ACI 440) = 247653.332$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 $\ln(11.3) \sin + \cos$  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) = 470.00  
 $f_{fe}((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 359638.026$   
 $bw * d = \rho * d^2 / 4 = 125663.706$

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  $\theta = 5.3113353E-021$   
 $y = (M_y * L_s / 3) / E_{eff} = 0.00946974$  ((4.29), Biskinis Phd))  
 $M_y = 4.4260E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 1500.00  
 From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} * E_c * I_g = 2.3369E+013$   
 $\text{factor} = 0.30$   
 $A_g = 196349.541$   
 Mean concrete strength:  $f'_c = (f'_c_{\text{jacket}} * \text{Area}_{\text{jacket}} + f'_c_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$   
 $N = 7387.347$   
 $E_c * I_g = E_{c_{\text{jacket}}} * I_{g_{\text{jacket}}} + E_{c_{\text{core}}} * I_{g_{\text{core}}} = 7.7898E+013$

Calculation of Yielding Moment  $M_y$

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

$M_y = \text{Min}(M_{y_{\text{ten}}}, M_{y_{\text{com}}}) = 4.4260E+008$   
 $y$  ((10a) or (10b)) = 1.3430729E-005  
 $M_{y_{\text{ten}}} (8a) = 4.4260E+008$   
 $\delta_{\text{ten}} (7a) = 65.19069$   
 error of function (7a) = 0.00234593  
 $M_{y_{\text{com}}} (8b) = 7.6083E+008$   
 $\delta_{\text{com}} (7b) = 64.49917$   
 error of function (7b) = -0.0073398  
 with  $e_y = 0.003125$   
 $e_{co} = 0.002$   
 $a_{pl} = 0.45$  ((9c) in Biskinis and Fardis for FRP Wrap)  
 $d1 = 44.00$   
 $R = 250.00$   
 $v = 0.0011297$   
 $N = 7387.347$   
 $A_c = 196349.541$   
 $= 0.29185858$   
 with  $f'_c$  ((12.3), ACI 440) = 33.3038  
 $f_c = 30.00$   
 $f_l = 1.05384$   
 $k = 1$   
 Effective FRP thickness,  $tf = NL * t * \cos(b1) = 1.016$   
 $e_{fe}((12.5) \text{ and } (12.7)) = 0.004$



Ef = 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 JCC1 of floor 1

At local axis: 3

Integration Section: (b)

## Calculation No. 16

column C1, Floor 1

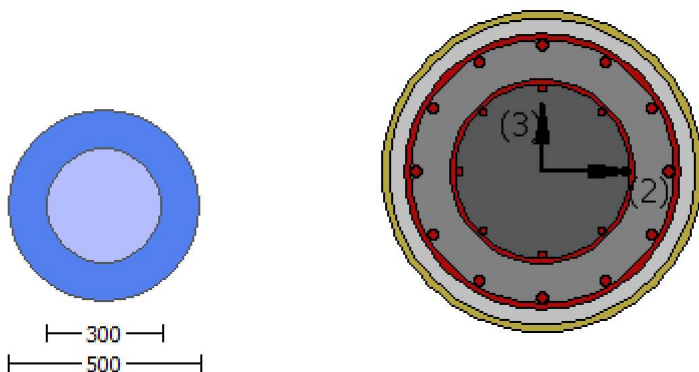
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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  
Jacket  
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 781.25$   
Existing Column  
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
#####  
External Diameter,  $D = 500.00$   
Internal Diameter,  $D = 300.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.50688  
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,  $V_a = 4.1010657E-031$   
EDGE -B-  
Shear Force,  $V_b = -4.1010657E-031$   
BOTH EDGES  
Axial Force,  $F = -7389.214$   
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,  $V_e/V_r = 0.45961884$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$   
with  
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 4.4703E+008$   
 $\mu_{u1+} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction  
which is defined for the static loading combination  
 $\mu_{u1-} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment  
direction which is defined for the static loading combination  
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 4.4703E+008$   
 $\mu_{u2+} = 4.4703E+008$ , 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

Mu2- = 4.4703E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu1+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TDY: fcc = fc\* c = 45.20626  
conf. factor c = 1.50688  
fc = 30.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25  
lb/d = 1.00  
d1 = 44.00  
R = 250.00  
v = 0.00112412  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.36292832

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 = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TDY: fcc = fc\* c = 45.20626  
conf. factor c = 1.50688  
fc = 30.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 781.25  
lb/d = 1.00  
d1 = 44.00  
R = 250.00  
v = 0.00112412  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.36292832

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

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

$$\mu_u = 4.4703E+008$$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TB DY:  $f_{cc} = f_c \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio  $l_b/d$

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

Calculation of  $\mu_u$ -

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

$$\mu_u = 4.4703E+008$$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TB DY:  $f_{cc} = f_c \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio  $l_b/d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 648405.308$

Calculation of Shear Strength at edge 1,  $V_{r1} = 648405.308$

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

$V_{c0} = 648405.308$

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

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

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

$= 1$  (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_c \cdot \text{jacket} \cdot \text{Area}_{\text{jacket}} + f'_c \cdot \text{core} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$   
 $\mu_u = 2.1425332E-011$   
 $\mu_v = 4.1010657E-031$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7389.214$   
 $A_g = 196349.541$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$   
 $V_{s1} = 308425.138$  is calculated for jacket, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s2}$  is multiplied by  $Col2 = 0.00$   
 $s/d = 1.04167$   
 $V_f ((11-3)-(11.4), ACI 440) = 247653.332$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 470.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 440464.828$   
 $b_w \cdot d = \sqrt{4} \cdot d \cdot d / 4 = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 648405.308$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{Col0}$   
 $V_{Col0} = 648405.308$   
 $knl = 1$  (zero step-static loading)

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

$\gamma_c = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_c \cdot A_{jacket} + f'_c \cdot A_{core}) / A_{section} = 27.84$ , but  $f'_c^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 2.1425332E-011$   
 $\mu_v = 4.1010657E-031$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7389.214$   
 $A_g = 196349.541$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$   
 $V_{s1} = 308425.138$  is calculated for jacket, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s2}$  is multiplied by  $Col2 = 0.00$

$s/d = 1.04167$   
 $V_f((11-3)-(11.4), \text{ACI 440}) = 247653.332$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $tf_1 = NL \cdot t / \text{NoDir} = 1.016$   
 $df_v = d$  (figure 11.2, ACI 440) = 470.00  
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 440464.828$   
 $bw \cdot d = \rho \cdot d^2 / 4 = 125663.706$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1  
 At local axis: 3  
 -----

-----  
 Start Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1  
 At Shear local axis: 2  
 (Bending local axis: 3)  
 Section Type: rcjcs

Constant Properties

-----  
 Knowledge Factor,  $\phi = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
 Concrete Elasticity,  $E_c = 25742.96$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 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  
 Jacket  
 New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 781.25$   
 Existing Column  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
 #####  
 External Diameter,  $D = 500.00$   
 Internal Diameter,  $D = 300.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.50688  
 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,  $V_a = -2.5110955E-047$

EDGE -B-

Shear Force,  $V_b = 2.5110955E-047$

BOTH EDGES

Axial Force,  $F = -7389.214$

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,  $V_e/V_r = 0.45961884$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$  with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 4.4703E+008$

$Mu_{1+} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 4.4703E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 4.4703E+008$

$Mu_{2+} = 4.4703E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 4.4703E+008$ , 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),  $M_u$

$M_u = 4.4703E+008$

$\phi = 0.97738438$

$\phi' = 0.86668818$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY:  $f_{cc} = f_c^* \quad c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

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),  $\mu$   
 $\mu = 4.4703\text{E}+008$

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

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),  $\mu$   
 $\mu = 4.4703\text{E}+008$

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 45.20626$

conf. factor  $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

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 = 4.4703E+008

= 0.97738438  
' = 0.86668818  
error of function (3.68), Biskinis Phd = 40566.604  
From 5A.2, TBDY:  $f_{cc} = f_c' \cdot c = 45.20626$   
conf. factor  $c = 1.50688$   
 $f_c = 30.00$   
From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 781.25$   
 $l_b/l_d = 1.00$   
 $d_1 = 44.00$   
 $R = 250.00$   
 $v = 0.00112412$   
 $N = 7389.214$   
 $A_c = 196349.541$   
=  $\cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.36292832$

## Calculation of ratio $l_b/l_d$

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

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 648405.308$

Calculation of Shear Strength at edge 1,  $V_{r1} = 648405.308$

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

$V_{Col0} = 648405.308$

$k_{nl} = 1$  (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)  
Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot \text{Area}_{jacket} + f_c'_{core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 27.84$ , but  $f_c'^{0.5} \leq 8.3$   
MPa ((22.5.3.1, ACI 318-14))  
 $M/Vd = 2.00$   
 $\mu_u = 2.0093280E-011$   
 $\mu_v = 2.5110955E-047$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7389.214$   
 $A_g = 196349.541$   
From ((11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$   
 $V_{s1} = 308425.138$  is calculated for jacket, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $\text{Col1} = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s2}$  is multiplied by  $\text{Col2} = 0.00$   
 $s/d = 1.04167$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 247653.332  
 $f = 0.95$ , 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 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) = 470.00

$f_{fe}$  ((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:  $V_s + V_f \leq 440464.828$

$b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 648405.308$

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

$V_{Col0} = 648405.308$

$k_{nl} = 1$  (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).

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

Mean concrete strength:  $f'_c = (f'_c \cdot A_{\text{jacket}} + f'_c \cdot A_{\text{core}}) / A_{\text{section}} = 27.84$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$  is calculated for jacket, with:

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

$f_y = 625.00$

$s = 100.00$

$V_{s1}$  is multiplied by  $\phi_{Col1} = 1.00$

$s/d = 0.25$

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

$A_v = \frac{1}{2} \cdot A_{\text{stirrup}} = 78956.835$

$f_y = 525.00$

$s = 250.00$

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

$s/d = 1.04167$

$V_f$  ((11-3)-(11.4), ACI 440) = 247653.332

$f = 0.95$ , 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  $\theta_i$ , 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) = 470.00

$f_{fe}$  ((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:  $V_s + V_f \leq 440464.828$

$b_w \cdot d = \frac{1}{4} \cdot d \cdot d = 125663.706$

End Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcjcs

#### Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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,  $E_s = 200000.00$

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

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,  $N_{oDir} = 1$

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = 0.10299595$

Shear Force,  $V_2 = 4667.709$

Shear Force,  $V_3 = 1.6819047E-013$

Axial Force,  $F = -7387.347$

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:  $As_{l,mid} = 1017.876$

Mean Diameter of Tension Reinforcement,  $Db_L = 18.00$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = * u = 0.0523278$

$u = y + p = 0.0523278$

- Calculation of  $\rho_y$  -

$$\rho_y = (M_y * L_s / 3) / E_{eff} = 0.00189395 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 4.4260E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 300.00$$

$$\text{From table 10.5, ASCE 41_17: } E_{eff} = \text{factor} * E_c * I_g = 2.3369E+013$$

$$\text{factor} = 0.30$$

$$A_g = 196349.541$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * A_{\text{jacket}} + f_c'_{\text{core}} * A_{\text{core}}) / A_{\text{section}} = 27.84$$

$$N = 7387.347$$

$$E_c * I_g = E_{c_{\text{jacket}}} * I_{g_{\text{jacket}}} + E_{c_{\text{core}}} * I_{g_{\text{core}}} = 7.7898E+013$$

Calculation of Yielding Moment  $M_y$

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

$$M_y = \text{Min}(M_{y_{\text{ten}}}, M_{y_{\text{com}}}) = 4.4260E+008$$

$$\rho_y \text{ ((10a) or (10b))} = 1.3430729E-005$$

$$M_{y_{\text{ten}}} \text{ (8a)} = 4.4260E+008$$

$$\rho_{y_{\text{ten}}} \text{ (7a)} = 65.19069$$

$$\text{error of function (7a)} = 0.00234593$$

$$M_{y_{\text{com}}} \text{ (8b)} = 7.6083E+008$$

$$\rho_{y_{\text{com}}} \text{ (7b)} = 64.49917$$

$$\text{error of function (7b)} = -0.0073398$$

$$\text{with } e_y = 0.003125$$

$$e_{co} = 0.002$$

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

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.0011297$$

$$N = 7387.347$$

$$A_c = 196349.541$$

$$= 0.29185858$$

$$\text{with } f_c' \text{ ((12.3), ACI 440)} = 33.3038$$

$$f_c = 30.00$$

$$f_l = 1.05384$$

$$k = 1$$

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

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

$$E_f = 64828.00$$

Calculation of ratio  $l_b/d$

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

- Calculation of  $\rho_p$  -

$$\text{From table 10-9: } \rho_p = 0.05043385$$

with:

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

$$\text{shear control ratio } V_y E / V_{co} I_{OE} = 0.45961884$$

$$d = d_{\text{external}} = 0.00$$

$$s = s_{\text{external}} = 0.00$$

$$t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00660658$$

$$\text{jacket: } s_1 = A_{v1} * ( \pi * D_{c1} / 2 ) / ( s_1 * A_g ) = 0.0027646$$

$$A_{v1} = 78.53982, \text{ is the area of stirrup}$$

$$D_{c1} = D_{\text{ext}} - 2 * \text{cover} - \text{External Hoop Diameter} = 440.00, \text{ is the total Length of all stirrups parallel to loading}$$

(shear) direction

$$s_1 = 100.00$$

$$\text{core: } s_2 = A_{v2} * ( \pi * D_{c2} / 2 ) / ( s_2 * A_g ) = 0.00046968$$

$$A_{v2} = 50.26548, \text{ is the area of stirrup}$$

$$D_{c2} = D_{\text{int}} - \text{Internal Hoop Diameter} = 292.00, \text{ is the total Length of all stirrups parallel to loading (shear)}$$

direction

$$s_2 = 250.00$$

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.

For the normalisation  $f_s$  of jacket is used.

$$N_{UD} = 7387.347$$

$$A_g = 196349.541$$

$$f_{cE} = (f_{c\_jacket} \cdot Area\_jacket + f_{c\_core} \cdot Area\_core) / section\_area = 27.84$$

$$f_{yE} = (f_{y\_ext\_Long\_Reinf} \cdot Area\_ext\_Long\_Reinf + f_{y\_int\_Long\_Reinf} \cdot Area\_int\_Long\_Reinf) / Area\_Tot\_Long\_Rein = 21219958E-314$$

$$f_{yE} = (f_{y\_ext\_Trans\_Reinf} \cdot Area\_ext\_Trans\_Reinf + f_{y\_int\_Trans\_Reinf} \cdot Area\_int\_Trans\_Reinf) / Area\_Tot\_Trans\_Rein = 610.4781$$

$$\rho_l = Area\_Tot\_Long\_Rein / (A_g) = 0.015552$$

$$f_{cE} = 27.84$$

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End Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1

At local axis: 3

Integration Section: (b)

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